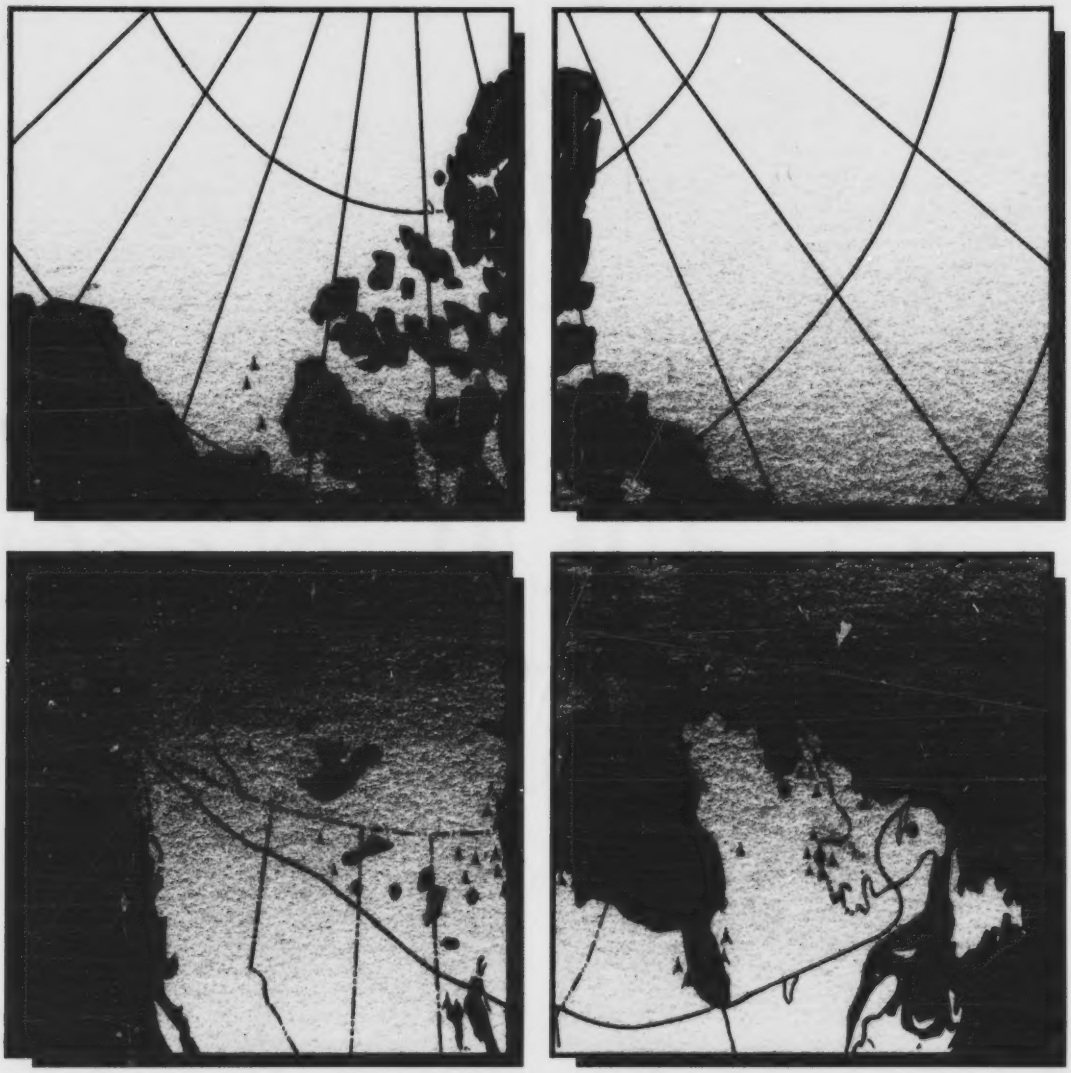
STUDENT RESEARCH IN CANADA'S NORTH

•

LES RECHERCHES DES ÉTUDIANTS DANS LE NORD CANADIEN



Proceedings of the National Student Conference on Northern Studies
November 18–19, 1986
Actes de la Conférence nationale des étudiants en études nordiques
18–19 novembre 1986

Editors:
W. Peter Adams
Peter G. Johnson

ASSOCIATION OF CANADIAN UNIVERSITIES FOR NORTHERN STUDIES
ASSOCIATION UNIVERSITAIRE CANADIENNE D'ÉTUDES NORDIQUES

STUDENT RESEARCH IN CANADA'S NORTH

LES RECHERCHES DES ÉTUDIANTS DANS LE NORD CANADIEN

Proceedings of the National Student Conference on Northern Studies
November 18–19, 1986
Actes de la Conférence nationale des étudiants en études nordiques
18–19 novembre 1986

Editors:
W. Peter Adams
Peter G. Johnson

ASSOCIATION OF CANADIAN UNIVERSITIES FOR NORTHERN STUDIES
ASSOCIATION UNIVERSITAIRE CANADIENNE D'ÉTUDES NORDIQUES

©ACUNS 1988

130 Albert Street, Suite 1915
Ottawa, Canada K1P 5G4
Tel: (613) 238-3525

Deposited at the National Library of Canada
Ottawa
1988

ISBN 0-921421-02-8

Financial assistance towards the publication of these Proceedings
was received from the Department of Indian and Northern Affairs.

TABLE OF CONTENTS
TABLE DES MATIÈRES

- Préface/Preface 1
- Address to the National Student Conference on Northern Studies, Ottawa, Ontario, November 18, 1986, by the Honourable Bill McKnight 2
- Introduction 3
- Éléments d'une Nordologie — A Science of the North by Professor Louis-Edmond Hamelin, Laval University 16

A. PHYSICAL SCIENCES
SCIENCES PHYSIQUES

- Cretaceous Volcanism Associated with Development of the Sverdrup Basin, Ellesmere Island, Arctic Archipelago — Preliminary Results from Recent Mapping by Jennifer L. Bates 23
- Morphologie et sédimentologie des moraines de de Geer de la région de la rivière La Grande, Québec, par Luc Beaudry 30
- A First Approximation of Frozen Soil Creep, Melville Island, Arctic Canada, by L. Bennett 35
- Early Faulting in the Northern Labrador Trough by Paul Budkewitsch, Normand Goulet and Henry S. de Romer 39
- Preliminary Report on the Petrology and Geochemistry of Basalts of the Permian Esayoo Formation, Sverdrup Basin, Canadian High Arctic by B.I. Cameron 43
- Pollen — Sediment Relationships in the Ruby Range, Yukon Territory by Ian Campbell 50
- Pétrographie des sédiments, outil de reconstruction d'écoulements glaciaires au s.-o. du Yukon par Véronique Dewez 55
- Caractéristiques physiques et chimiques de trois tourbières subarctiques dans la région de Schefferville, Québec, par Marisa Ditata 68
- On the Chemical Influence of a Decaying Subarctic Lake Ice Cover, Schefferville, Quebec, by Peter T. Doran 72
- La partie nord de la fosse du Labrador: zone de chevauchement majeure? par Francis Falardeau 83
- Underwater Camera System Used in Pangnirtung Fiord, Baffin Island, by John Glew 85
- Topographic Change of the Meighen Ice Cap, Meighen Island, N.W.T., by Thomas Westby Haythornthwaite 87
- Drainage Characteristics of a Glacier Dammed Lake, Kaskawulsh Glacier Basin, Southwest Yukon Territory, by Jennifer N. Kasper and Peter Johnson 92
- The Freezing and Thawing of a Subarctic Fen, Schefferville, Quebec, by C.M. Kingsbury and T.R. Moore 98
- Glaciation locale pendant le pléistocène supérieur et l'holocène dans la chaîne Ruby, au sud-ouest du territoire du Yukon par Diane Lacasse et Peter Johnson 103
- Sedimentology and Stratigraphy of Coal-Bearing Cretaceous — Tertiary Strata on the Southeast Coast of Baffin Island, by A.B. Langille and E.T. Burden 111
- Modification of the Great Whale River, Québec, Plume During Ice Breakup by S. Lepage and R.G. Ingram 120
- Altération des substrats rocheux et rôle du soulèvement gélival dans la formation de champs de blocaille en Hudsonie par Yves Michaud et Jean-Claude Dionne 127
- Calibration and Use of Landsat Data in Subarctic Terrain Analysis, Ruby Range, Yukon Territory by Joan E. Moulton and Steven E. Franklin 128
- Photosynthetic Action Spectra of Arctic Ice Algae, Resolute Bay, N.W.T., November, 1986 by Robert Palmer and Marlon R. Lewis 133
- The Conceptual Development of a New Form of Upward — Acting Icebreaker Bow by Bruce Paterson ... 144
- Phytogeographical Studies in the Kluane Lake Region, Southwestern Yukon Territory by Alain P. Roy 157
- Évolution structurale des talus d'éboulis, Lac à l'Eau Claire, Québec subarctique par Nicolas St-Cyr 164
- Lake Evaporation in the Hudson Bay Lowlands by James David Smith 165
- Physio-Chemical Evaluation of Water in Tundra Ponds and Precipitation Samples from Iqaluit (Frobisher Bay), N.W.T., July 1985, by Janet Stavinga 169
- A Study of an Active Layer Soil with an Unusual Thermal Regime, Near Schefferville, P.Q.: Preliminary Results by K.J.L. Stoker Jr. 174
- Le climat des cavernes Tsi-Tché-Han et Bear Cave, Nord du Yukon, Canada, par Pierre Thibaudeau 177
- An Assessment of Aerial Photographs as a Source for Surrogate Field Measurements of Ice Jams in the Liard/MacKenzie Rivers, N.W.T., by Shelley Watson 187
- Holocene Land Emergence, Western Simpson Peninsula, N.W.T., by Andrew Webster 203
- The Reconstruction of Paleoenvironmental changes in Truelove Lowland, Devon Island, N.W.T., by Robert B. Young, Peter Kelly, Andrew Heyes, Kim Law and Roger H. King 215
- Engineered Materials for the Canadian Arctic Offshore, by S.B. Young 220
- Canadian Permafrost Distribution and Thickness Data Collection: A Discussion, by S. Young and A.S. Judge 223

B. LIFE SCIENCES
SCIENCES BIOLOGIQUES

- Limitations on Impact Assessment as a Tool for "Balanced" Development in the North: Lessons from The Beaufort Environmental Assessment and Review Process, by Rebecca Aird 233
- Solifluction and its Influence on Vegetation and Stream Water Chemistry in Small Permafrost Basins, Axel Heiberg Island, N.W.T., by C. Allan, S. Schiff, D. Pierson, M. English, M. Ecclestone and W.P. Adams 239
- Further Evidence of Hermaphroditism in Lepidurus Arcticus (Crustacea, Notostraca) from the Melville Peninsula Area, N.W.T., by Margaret J. Beaton and P.D.N. Hebert 253
- Nutrient Status of 25-To-30-Year-Old Open Forest and Tundra White Spruce, Near Churchill, Manitoba, by Catherine V. Bentley 257
- Correlations Between Plant Cover, Biomass and Soil Moisture Parameters from Nine Arctic Sites, by Jean-François Bergeron 262
- Biochemical Differences Between Two Related Species of Leptodiaptomus (Copepoda), by Marc G. Boileau and Paul D.N. Hebert 266
- The Arctic Char Winter Fishery of Kangiqsualujjuaq, Quebec, by T. Boivin and G. Power 269
- Some Implications of Hydroelectric Development and Related Engineering Projects in Northern Canada, by Allan R. Chapman 275
- Oxygen Depletion Rates in Subarctic Lakes Near Schefferville, Quebec, by Oksana Choulik 280
- Nurses and Indian Elders/Traditional Healers: An Exploration of the Contact Between Non-Traditional and Traditional Health Care Providers on Indian Reserves and in Health Centres in Manitoba, by David Gregory 286
- Demographic Changes in Cyclic Populations of Arctic Fox (Alopex Lagopus) at Eskimo Point, N.W.T., Canada, by Michael N. Hall and F.F. Mallory 289
- Distribution and Abundance of the White Whale (Delphinapterus Leucas) in Relation to the Physical and Chemical Characteristics of the Churchill River Estuary by S.E. Hansen, P.D. Watts, and F.F. Mallory .. 293
- Habitat Tolerance of Dryas Integrifolia from Studies Near Churchill, Manitoba and Alexandra Fiord, Ellesmere Island, N.W.T., by Gordon T. Hart 297
- The Distribution of Bowhead Whales (Balaena Mysticetus) in the Southeast Beaufort Sea, July — September, 1984, by Lois A. Harwood and Gary A. Borstad 305
- The Bryogeographical Significance of the Torngat Mountains, Northern Labrador, by Terry A. Hedderson . 312
- Herbivory, Lesser Snow Geese and the Production of Saltmarsh Vegetation, Northern Manitoba, by David S. Hik 326
- Assessing Trail Conditions in the Canadian North: A Case Study in Two National Parks, by Peter I. Hutchison 330
- Temporal Aspects of the Distribution, Abundance and Behaviour of Beluga Whales (Delphinapterus Leucas) in the Churchill Harbour, by P.D. Idle, P.D. Watts, and F.F. Mallory 338
- The Responses of Sedge Communities to Herbivory, La Pérouse Bay, Manitoba, by Peter Kotanen 342
- Energetics of the Sub-Ice Amphipod Weyprechtia Pinguis, by Patricia N.B. Lewis 348
- Northern Resource Decision-Making: A Case Study of the Faro Mine, Yukon Territory, by Bruce A. Lourie 348
- The Future of Parks Canada North of 60, by Shona MacLachlan 352
- Quantitative Vegetation Analysis, Southern Baffin Island — Phase One: Iqaluit Area, by Lin Maus 358
- Early Tertiary Fossil Cedars of the Canadian High Arctic, by E.E. McIver and J.F. Basinger 362
- A Field Survey of Respiration Rates in Leaves of Arctic Plants, by Amy McNulty, W. Raymond Cummins and Andrew Pellizzari 368
- The Beaufort Sea Boundary Dispute (Canada/Alaska): A Discussion, by Peter Murphy 368
- The Development of Northern Nursing in Desmarais, Alberta, by Wendy Neander 373
- Growth Pattern of High Arctic Species of Saxifraga Tricuspidata Rottb. and S. Oppositifolia L., Igloolik Island, N.W.T., by Carey Ogilvie and Martin Lewis 377
- Environmental Assessment Mechanisms in the Yukon Territory: A Review of Legislative and Administrative Procedures by Donna Pawlowski 384
- Wetlands as Waste Repositories?: Solute Transport in Peat by Jonathan S. Price and Ming-ko Woo 392
- Muskox Activity Patterns and Plant Community Preferences on Central Ellesmere Island, N.W.T. by Martin Raillard, Thomas Rahn and Joseph Svoboda 396
- Diet and Distribution of Collared Lemmings and Meadow Voles Near Churchill, Manitoba, Canada, by Peter A. Scott 399
- Effect of Native Harvest on the Population Dynamics of the Northern Muskrat (Ondatra Zibethicus Spatulatus), by Mark R. Simpson 404
- Agonistic Interactions and Foraging Strategies of Captive and Wild Arctic Fox, by L.G. Wakely and F.F. Mallory 406
- Vegetational History During the Last 1230 Years in the Bear Lakes Area, Aishihik Basin, Yukon Territory, by Xiacheng Wang 409

C. HUMAN SCIENCES
SCIENCES HUMAINES

- Personal Names, Numbers and Northern Policy: Inuit Identity in Canada, by Valerie Alia 417

- The Northern Heritage Society, Notes for a presentation by Madeline d'Argencourt and Debbie Webster .. 420
- Eighteenth Century Inuit Occupation of the Strait of Belle Isle, by Reginald Auger 422
- Relations inter-ethniques et dynamique de développement en milieu nordique, par Michel Barbeau 429
- Appropriate Education for the Inuk Geography Student, by Ken Beardsall 433
- Les beaux sauvages de la Floride, de la Virginie et du Canada (1675–1723) La muséologie rencontre l'anthropologie, par Denyse Bilodeau et Claude Gagnon 437
- Design System of Moccasin Ornamentation of Janvier Band Chipewyan, by Cecile M. Clayton 445
- Drum-Dance Music of the Inuit of Northern Baffin Island: An Analysis of One Song and its Variants, by Paula Conlon 453
- Les facteurs socio-culturels associés à l'étiologie de l'otite moyenne chez les enfants Inuit du Nouveau-Québec, par Rose Dufour 458
- An Investigation of Writing Across the Curriculum in an Eastern Arctic School, by Marta Fasiolo and Ronald Mackay 465
- The Impact of the Snowmobile in Makkovik, Labrador, by Violet Ford 471
- Système circumpolaire et désarmement régional, par Michel Frédérick 473
- Mammoth Bone Breakage Patterns from Locality 11A, Old Crow, Northern Yukon Territory, by T. Max Friesen 479
- Les femmes Inuit et le développement, par Hélène Guay 485
- Reserve Development and the Indian Act: The Case of The Pas Reserve, Manitoba, by Judy Head 489
- Buying Cultural Permanence: COPE and the Federal Government of Canada, by Barry A. Hochstein 494
- Inuit Folk-Ornithology in the Povungnituk Region of Northern Quebec, by Martha Johnson 499
- Native Rights and Liberalism, by William Kymlicka 505
- Histoire de l'utilisation des ressources naturelles par les Inuit dans les estuaires de Kangiqsujuaq: perspective ethnoarchéologique, par Yves Labrèche 512
- An Exercise in Sovereignty: The Canadian Government and the Relocation of Inuit to the High Arctic In 1953, by Keith Lowther 517
- Représentativité inuit au sein des postes de gestion dans les Territoires-du-Nord-Ouest: De la théorie à la pratique, par Claire Mailhot 522
- Spousal Assault Amongst the Dene: An Historical Perspective on a Present-Day Problem, by Shirley M. McGrath 529
- Attitudes About Sustainable Development in Yukon, by David McRobert 533
- Folkloric Exchange Between Labradorians and Newfoundland Fishing Families "On The Labrador", by Clara J. Murphy 540
- Valuing Traditional Activities in the Northern Native Economy: the Case of Old Crow, Yukon Territory, by Sheilagh C. Murphy 544
- Cooperative Planning and Management of National Parks and National Wildlife Areas in the Northwest Territories, by David A. Neufeld 548
- Historical Variations in Copper and Caribou Inuit Skin Clothing Fashions, by Jill Oakes 555
- Pattern Development in Eskimo Point, N.W.T., by Jill Oakes 560
- The Porden Point Thule Project: Current Problems in Thule Culture Research, by Robert W. Park 564
- Semantics of Cree Verbs of Possession: Preliminary Report of a Quantificational Semantic Study in Northern Ontario, by Floyd W. Rudmin 568
- Développement des ressources ludiques dans les localités Cries de la Baie James, Québec 1982–1986, par Diom Saganash 575
- 'Action-Reaction': The Evolution of the Native Economy of The Pas and Norway House Agencies: 1870–1939, by Bruce Stadfeld 577
- Prehistoric Inland Adaptations in Southern Baffin Island, N.W.T., by Douglas R. Stenton 586
- The Imagined Reality of the Canadian North, by Douglas A. West 590

PRÉFACE

Il m'est très agréable de présenter les Actes de cette première Conférence Nationale des Étudiants en Études Nordiques pour deux raisons. La première tient au fait qu'en organisant cette conférence, l'Association universitaire canadienne d'études nordiques innovait puisqu'elle permettait, pour la première fois au Canada, de rassembler en un même lieu, un grand nombre d'étudiants des 2e et 3e cycles leur donnant ainsi l'occasion de communiquer les résultats de leurs travaux et d'échanger sur plusieurs autres sujets d'intérêt commun. De plus, cette conférence fournissait l'occasion aux étudiants des diverses sciences naturelles et humaines de s'identifier non seulement à un événement de grande envergure, mais aussi d'enrichir une tradition vieille maintenant d'une décennie, c'est-à-dire depuis l'établissement de l'AUCEN.

Cette conférence fut co-commandité par le ministre des Affaires indiennes et du Nord l'honorable Bill McKnight, lequel a accordé son plus entier appui à cet événement au moment ou il devenait le titulaire de ce ministère. Il a d'ailleurs concrètement manifesté son intérêt en venant à la conférence et en visitant avec une grande attention les présentations d'affiches thématiques. Il a pris le soin de s'informer abondamment de la matière et de la portée des résultats scientifiques ainsi présentés pour les diverses régions nordiques du Canada.

Des points de vue logistique, technique, scientifique et relationnel, cette conférence fut un franc succès grâce aux talents d'organisation de notre directeur général d'alors, le Dr Peter Adams, mais aussi du travail assidu et compétent du comité organisateur, composé d'étudiants et de professeurs de la région d'Ottawa. Qu'ils soient tous et chacun remerciés pour les efforts qu'ils ont déployés en notre nom et nous avons d'ores et déjà l'assurance que ces énergies produiront de nombreuses retombées. On est certes déjà au courant que l'Association universitaire canadienne d'études nordiques, en collaboration avec le ministère des Affaires indiennes et du Nord, est à préparer les plans d'une seconde Conférence Nationale des Étudiants en Études Nordiques qui aura lieu les 23 et 24 du mois de novembre 1988 à Ottawa. Cette première conférence représente déjà pour l'AUCEN un magnifique fleuron. En effet, les travaux qui ont été présentés à la conférence sont de bonne qualité et de nombreux liens d'amitiés se sont créés entre les jeunes chercheurs nordiques des différentes universités canadiennes. Notre association oeuvre ainsi à la réalisation de l'un de ses mandats, à savoir, la promotion et soutien des jeunes chercheurs nordiques ayant un rattachement universitaire afin qu'ils puissent assurer la relève et consolider la tradition que tous ensemble nous construisons.

J'adresse également mes remerciements aux co-éditeurs de ces Actes les Drs Peter Adams et Peter Johnson. Tout ceux qui ont l'expérience de ce travail de rédaction savent l'énergie et la compétence qu'il faut déployer pour mener à bonne fin une tâche de cette envergure. A ce propos, la lecture des épreuves par Mme Eileen Van Heyst représente une contribution qui est appréciable et appréciée. Notre gratitude s'exprime aussi à l'endroit des universités et autres organismes publics et privés qui ont contribué à défrayer les coûts de cette entreprise. Enfin comment ne pas remercier et féliciter à la fois toutes celles et ceux qui ont présenté des travaux à l'occasion de cette conférence. Grâce aux efforts conjugés de ces divers partenaires, nous assurons le progrès des études dans le Nord, et pouvons espérer que les résultats de ces travaux bénéficient de plus en plus aux collectivités et populations Nordiques.

Marc-Adélard Tremblay
Président
l'Association universitaire canadienne
d'études nordiques

PREFACE

I am pleased to preface these proceedings of this first National Student Conference on Northern Studies for two reasons. The first is that, in organizing this conference ACUNS was innovating since, for the first time in Canada, it allowed a large number of students with northern interests to meet together to present the results of their work and to discuss many other matters of mutual interest. In addition, this conference allowed students from many disciplines in the natural and social sciences not only to take part in a significant national event but to enrich the traditions of northern scholarship promoted by ACUNS for the last ten years.

This conference was co-sponsored by the Minister of Indian and Northern Affairs, the Hon. Bill McKnight, who gave it his full support at a time when he had just begun his tenure in that Ministry. Mr. McKnight has shown his interest by coming to the conference and visiting at some length the poster presentations. He took special care to make himself cognizant of the scientific results thus being reported from the various regions of northern Canada.

This conference was a great success from a logistic, technical, scientific and personal point of view thanks to the talents of our then Executive Director, Dr. Peter Adams, and to the competent and assiduous work of the organizing committee, made up of students and faculty from the Ottawa region. Our thanks go to all of them for these efforts on our behalf and we have the assurance that this work will bear fruit. We are now awaiting the Second National Student Conference on Northern Studies, to be held in Ottawa on 23-24 November 1988, also sponsored by ACUNS and the Ministry of Indian and Northern Affairs. The first conference was an excellent endeavour. The works presented were of good quality and there were many links established among young northern researchers from many Canadian universities. Our Association is thus fulfilling one of its primary mandates, that is supporting young northern university scholars so that the tradition of northern scholarship that we are promoting may continue into the next generation.

I also thank the co-editors of these Proceedings, Drs. Peter Adams and Peter Johnson. Those who have editing experience know what a difficult and time-consuming task it is to see a work of this scope published. In this respect, Mrs. Eileen van Heyst has made a significant contribution in galley proofreading which is highly appreciated. We also thank the universities and other public and private organizations who helped defray the costs of this event. And, lastly, I wish to thank and to congratulate those who presented their work at this conference. It is thus that we assure the continuing success of northern studies, so that the results of these studies benefit more and more the communities and peoples of the North.

Marc-Adélard Tremblay,
President,
Association of Canadian Universities
for Northern Studies.

ADDRESS BY THE HONOURABLE BILL McKNIGHT, MINISTER OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT TO NATIONAL STUDENT CONFERENCE ON NORTHERN STUDIES OTTAWA, ONTARIO, NOVEMBER 18, 1986

Ladies and gentlemen, I would like to welcome you here to this National Student Conference on Northern Studies.

It was my precedessor, the Honourable David Crombie, who made the decision that there should be this conference, an opportunity for students in Northern Studies to exchange ideas and discuss their interests in the North in a national forum. I am sure that, as in most conferences, you will learn more after the meeting than you do during. I am very pleased to be able to continue the support and the effort that my colleague started for these very worthwhile sessions.

The President, Marc-Adélard Tremblay, and the staff of ACUNS, along with the organizing committee, are the people who made this event possible. I am sure that they will continue in the future to promote events such as this.

Being from Saskatchewan, I would like to mention the two universities out there, the University of Saskatchewan and the University of Regina, which both have northern studies programs.

I hope later to visit the main pavillion, talk with some of you and look at some of the displays.

There is much benefit from events such as this, and from government departments being involved in programs that broaden horizons and allow young men and women an opportunity to take part in something that may become a career, but is certainly a learning experience.

There is much more to learn about the North, whether you are a Minister or whether you happen to be a man or woman in Canada who is interested in the North.

In the future I am sure that there will be professionals coming forward from the group of students here tonight. By becoming professionals, I hope that you will be able to bring to the northern part of Canada, that vast land with great opportunity, economic development that will allow the North to remain the North. Such development should allow the people who live there the opportunity to make a living and to maintain their life-style, while maintaining the ecology of the land where they live and in which many of them were born.

In the northern part of Canada, where the government is presently negotiating three land claim settlements, our attempt to settle has been going on for a long time. It is a complex issue but once we have arrived at settlements, there will be protection, there will be recognition of rights, and there will be the ability of all who live in the North to benefit from economic development.

One thing that we have commenced is offering, at a pace established by those men and women who live in the North, programs that are presently delivered by the Government of Canada, to be delivered by the people who are elected in Yukon and the Northwest Territories.

It is not necessary to have a paternalistic view of the North. The Members of the Legislative Assemblies of Yukon and N.W.T., the Cabinets, the legislators, and the residents can exercise their franchise in the very same manner, with the same lack or amount of intelligence that is exercised in the south. The present government is committed to turning over the programs and turning over the ability to govern, as quickly as is possible.

I want you all to bear in mind that in the past so many of us viewed the North as being the same; it did not matter whether it was eastern arctic or western arctic, low arctic or high arctic. But there are as many differences in the North among people, among regions, among life-styles, as there are in the south. I know from discussions with the people who live there, people who are involved, that they recognize these differences. These differences are something that I hope the government will be able to maintain, while assisting in the political development of the North.

As some of you may know, Stephen Leacock, when he talked about education, said that education is a peculiar process. You aim at one thing and you will hit another. You set out to look for the ultimate truth and you do not find it. Incidentally, you have acquired a cultivated mind.

I do not think that having a cultivated mind is something that anybody could say would not be beneficial to those who are involved in northern studies.

It is my pleasure to invite all of you to Parliament Hill tomorrow, when I will have the privilege of presenting this year's Centenary Medal for Northern Science to Dr. Louis-Edmond Hamelin.

It is a privilege to be a Minister and to give assistance in putting forward programs and conferences such as this, and to have that assistance recognized, and I want to thank you for that recognition. I applaud your efforts and hope we have an opportunity to do this again and see what progress we have made.

Thank you very much.

INTRODUCTION

The papers in this volume include the majority of the presentations made at the first National Student Conference on Northern Studies, held at the Conference Centre, Ottawa, 18-19 November 1986. The purpose of the Conference was to bring together the best Northern Studies students in Canada. The objective was that this "next generation" of Northern scholars should get to know each other and become familiar with each other's work. The meetings were organized into oral and poster sessions within which presenters were instructed to address 'their peers in *other* disciplines'. Behind this instruction, indeed, behind the design of the entire conference, was the belief that Northern Studies scholars should be (unusually) familiar with and sensitive to the multidisciplinary context of their research. It is no longer efficient or appropriate that, for example, a geophysicist should conduct research in the North without a strong appreciation of the social, political and historical contexts of his/her work, or that an historian working in Northern Studies should not be familiar with the environmental and political contexts of the research concerned. At the meetings, contacts were established between Northern students who live *and* study in the North, students who are northern residents studying in the South, and the large number who live in the South but conduct research in the North.

While in the oral and poster presentations students were instructed to address their peers in other disciplines, for the written versions they were instructed to address their peers *within* their disciplines. As a result, this volume inevitably lacks some of the academic and other cross currents which were such an important part of the meetings themselves.

Although the vast majority of presenters at the Conference were students, there were a number of non-student speakers specifically invited by the, largely student, Organizing Committee. Those presenters (and their topics) were: Nancy Doubleday, Inuit Tapirisat of Canada (cooperative research); Louis-Edmond Hamelin, Université Laval ("a science of the North"); F. Kenneth Hare, University of Toronto (the "greenhouse effect" and the Arctic); Rhoda Innuksuk, President, Inuit Tapirisat of Canada (the ITC's Youth Councils) and the Hon. Bill McKnight, Minister of Indian Affairs and Northern Development (keynote address). Jacques Gérin, Associate Deputy Minister, North, DINA, and Marc-Adélard Tremblay, President of ACUNS, gave short addresses on the importance of Northern Studies.

With the exceptions of the Hon. Bill McKnight and Dr. Hamelin, the recipient of the 1986 Northern Science Award, these speakers preferred not to have their addresses published. The finale of the Conference was the award ceremony, in the West Block of Parliament, at which Dr. Hamelin received his Award. The student delegates were

Dans les présents Actes figurent la plupart des communications présentées à la Conférence nationale des étudiants en Études nordiques, qui s'est déroulée les 18 et 19 novembre 1986 au Centre des conférences d'Ottawa. Son objet était de réunir les meilleurs étudiants en Études nordiques du Canada, afin que la "prochaine génération" de spécialistes du Nord aient pris des contacts mutuels et se soient familiarisés avec leurs travaux respectifs. Cette rencontre a pris la forme de séances de communications orales et de présentations graphiques, dont les auteurs avaient reçu la consigne de s'adresser à leurs "confrères *d'autres* disciplines".

Cette consigne, et même l'organisation de toute la Conférence, reflétaient la conviction selon laquelle les spécialistes du Nord devraient être (particulièrement) familiarisés avec le contexte pluridisciplinaire de leurs travaux, et qu'il leur faudrait y être attentifs. Par example, il n'apparâit plus suffisant ou approprié qu'un géophysicien mène des recherches dans le Nord sans tenir soigneusement compte de leur contexte social, politique et historique. De même, l'historien oeuvrant dans le Nord doit-il se familiariser avec le contexte politique et environnemental des recherches qu'il accomplit. Lors de la Conférence, les étudiants qui vivent et qui, *également*, étudient dans le Nord, ont pu établir des contacts avec les étudiants nord-canadiens qui étudient dans le Sud du pays, et avec ceux qui, très nombreux, y résident, mais mènent des recherches dans le Nord.

Alors que les auteurs des communications orales et des présentations graphiques avaient reçu pour consigne de s'adresser à leurs confrères d'autres disciplines, ceux qui présentaient des communications écrites devaient s'adresser à leurs collègues *de la même* discipline. C'est pourquoi ces Actes, inévitablement, ne reflètent pas les échanges interuniversitaires et interdisciplinaires qui ont constitué un aspect si important de la rencontre elle-même.

Bien que, lors de cette Conférence, la plupart des intervenants aient été des étudiants, un certain nombre de conférenciers non-étudiants avaient été invités par le Comité d'organisation, en grande partie formé d'étudiants. Voici quels étaient ces conférenciers et les sujets qu'ils ont traités: Mme Nancy Doubleday, Inuit Tapirisat of Canada (la recherche en collaboration); M. Louis-Edmond Hamelin, de l'Université Laval («Une science du Nord»); M.F. Kenneth Hare, de l'Université de Toronto («L'effet de serre et l'Arctique»); Mme Rhoda Innuksuk, présidente de l'Inuit Tapirisat of Canada (les conseils pour la jeunesse de l'Inuit Tapirisat); et l'honorable Bill McKnight, Ministre des Affaires indiennes et du Nord (allocution thématique). M. Jacques Gérin, Sous-ministre associé, Nord, MAIN, et M. Marc-Adélard Tremblay, président de l'AUCEN, ont présenté de brèves allocutions sur l'importance des Études nordiques.

invited to this event by the Hon. Bill McKnight, the principal sponsor of the Conference. Dr. Hamelin's address, which develops *his* multi-disciplinary view of Northern Studies, leads off this volume.

There were a number of other important presentations at the Conference which do not find expression in this volume. They included the following:

Ikpik - the Inuit International Youth Camp. This presentation, with Rhoda Innuksuk's address (see above) presented another dimension of the Inuit Tapirisat's youth work. Non-Inuit students have subsequently attended this annual camp. Further information is available from the ITC, 176 Gloucester Street, Third Floor, Ottawa, Ontario K2P 0A6 and from Higgins (1987).

Canada's Northern Field Stations - a presentation by ACUNS on more than 30 field stations in the North (see Fig. 1), part of the Association's ongoing effort to encourage more effective use of these facilities, among other things, to minimize the social and environmental impact of research in the North. For further information see Campbell *et al.* (1986) and Adams (1987 and in press).

The Northern Scientific Resource Centres of DINA - a display of three field stations maintained by the Ministry of Indian and Northern Affairs, at Iqaluit, Igloolik and Inuvik in the N.W.T. For further information, contact Harald W. Finkler, Chief, Scientific Affairs, Circumpolar and Scientific Affairs Directorate, Department of Indian and Northern Affairs, Ottawa, Ontario K1A 0H4.

The Northern Scientific Training Program, DINA - 25th Anniversary - this federal program has been the major source of funds for Canadian students working in the North. At the present time it assists more than 350 students each year. For an account of the Program, see Finkler (1987). The point of contact is Harald W. Finkler at the address given above.

The Northern Heritage Society, Yellowknife, N.W.T. Madeline d'Argencourt and Debbie Webster, two northern students attending high school in Ottawa, described the work of this Society in placing young northerners with scientific parties in the North. Notes for their presentation appear in this volume. For more details see Bielawski (1987). The point of contact is Northern Heritage Society, P.O. Box 475, Yellowknife, N.W.T. X1A 2N4.

Eastern Arctic Teacher Education Program, Iqaluit. This presentation, by Monica Ittusardjuat, Kate McDermott and Simon Okpakok, focussed on the role of this McGill University program in the Eastern Arctic. At present over one hundred students are working towards McGill degrees in the Program. Virtually all of the course work is conducted in the Arctic rather than on the main McGill campus in Montreal. For further details, see Wilman (1987) and Cram (1987). The point of contact is David Wilman, Principal, Eastern Arctic Teacher Training Program, Iqaluit, N.W.T. X0A 0H0.

Voices of the Eastern Arctic. This was a display of creative drawing, lithographs and mounted narrative material produced by young people of the Eastern Arctic. This material is a cultural study of the lives of Canada's northern youth. The exhibit has been displayed in Montreal and

À l'exception de l'Hon. Bill McKnight et de M. L.-E. Hamelin, lauréat du Prix de la recherche scientifique sur le Nord pour 1986, ces conférenciers ont préféré que leur allocution ne soit pas publiée. Le point culminant de la Conférence, soit la remise du Prix à M. Hamelin, se déroula dans l'Édifice de l'Ouest du Parlement. Les délégués étudiants y avaient été invités par l'honorable Bill McKnight, principal parrain de la Conférence. L'allocution de M. Hamelin, qui y développe *sa propre* perspective pluridisciplinaire sur les Études nordiques, ouvre les Actes.

Un certain nombre d'autres exposés importants, présentés à la Conférence, ne figurent pas dans les présents Actes; en voici quelques-uns:

Ikpik — Le camp international de la jeunesse inuit. Cet exposé, parallèlement à l'allocution de Mme Rhoda Innuksuk (voir ci-dessus), mettait en évidence un autre aspect de l'oeuvre de l'Inuit Tapirisat en matière de jeunesse. Les étudiants non inuit ont ultérieurement participé à ce camp annuel. On peut se procurer d'autres renseignements en s'adressant à l'ITC, 176 rue Gloucester, 3e étage, Ottawa, Ont. K2P 0A6, et en consultant l'ouvrage de Higgins (1987).

Les stations nordiques du Canada — Cet exposé de l'AUCEN au sujet de plus de 30 stations de terrain du Nord (voir fig. 1) s'inscrivait dans le cadre de l'effort permanent de l'Association visant à encourager une utilisation plus efficace de ces installations et, entre autres, à réduire le plus possible les répercussions de ces recherches sur la société et l'environnement nordiques. On peut obtenir d'autres renseignements en consultant les ouvrages de Campbell et coll. (1986) et Adams (1987, et sous presse).

Les Centres de ressources scientifiques sur le nord du MAIN. — Il s'agit d'une présentation graphique sur trois stations de terrain administrées par le Ministère des Affaires indiennes et du Nord à Iqaluit, Igloolik et Inuvik, dans les T. N.-O. On peut se procurer d'autres renseignements auprès de M. Harald W. Finkler, chef des Affaires scientifiques, Direction des Affaires circumpolaires et scientifiques, Ministère des Affaires indiennes et du Nord, Ottawa, Ont. K1A 0H4.

Le Programme de formation scientifique dans le Nord (MAIN) — 25e anniversaire. Ce programme de l'Administration fédérale constitue une importante source de financement des travaux des étudiants canadiens dans le Nord. Chaque année, il aide plus de 350 étudiants. On peut lire une description de ce Programme en consultant l'ouvrage de Finkler (1987); veuillez prendre contact avec M. Harald W. Finkler, à l'adresse mentionnée plus haut.

La Société du patrimoine culturel du Nord, à Yellowknife (T. N.-O.) Melles Madeleine d'Argencourt et Debbie Webster, deux élèves nord-canadiennes inscrites à une école secondaire d'Ottawa, y décrivent les efforts de cette Société pour faire inclure de jeunes Nord-canadiens dans des équipes de recherches scientifiques dans le Nord. Les remarques concernant leur exposé sont incluses dans les Actes. On peut obtenir d'autres détails en consultant l'ouvrage de Bielawski (1987). Le contact est assuré par la Northern Heritage Society, P.O. Box 475, Yellowknife, N.W.T., X1A 2N4.

Programme de formation des enseignants pour l'Arctique oriental (Iqaluit). Cet exposé de Melles Monica Ittusardjuat

Yellowknife and has toured Scandinavia. A book, produced by students at the Gordon Robertson Educational Centre, Iqaluit, based on the material, has been published by *Outcrop* of Yellowknife, see Shapiro (1987).

University Displays. Many universities displayed their ongoing Northern Studies programs. These were a special feature of the Conference. ACUNS/AUCEN has since encouraged the use of these displays (and the student poster papers) as a focus for on-campus activity. We believe that this encouragement has already had a positive effect on several campuses.

Measures of the state of Northern Studies in Canada

These Proceedings are a rather dry indication of a Conference which was a very exciting expression of the scale and scope of student involvement in Northern Studies across Canada. The Conference and the contents of this volume provide a sample of the level and nature of activity in Northern Studies in Canada's universities today.

A total of 193 students, from 33 universities, attended the meetings. There were 110 presentations (often multi-authored) as a result of which 101 papers appear in this volume. The list of attendees (Table 1) includes students whose homes are in the NWT (east and west), Yukon, northern Quebec, northern Labrador and other provincial Norths. It includes native (Inuit, Indian, and Metis) and non native students. Some of the Northerners were attending university in the south full time, others were attending full time in the North (see above re. EATEP), others were involved in Distance Education programs of various types. There are no universities in the Territories at present but several southern institutions operate there full time, complementing the work of Arctic College and Yukon College (see *Education, Research, Information Systems and the North*, ACUNS 1987, for articles on Arctic College and other aspects of higher education in the N.W.T. and on the roles of various universities there). The Provincial Norths are served by an even larger number of institutions, including on-site universities (see Adams and Parker 1987).

Table 2, *based on papers in this volume*, gives an indication of the distribution of the students by university, academic level and subject area. The academic level of each student author is indicated at the beginning of each of the papers in this volume. Figure 2 gives an indication of the geographical range *of fieldwork* upon which papers in this volume are based. Every major region of the Canadian North is represented, on land and at sea. Some papers, of course, cannot be mapped in this way either because of their scope (e.g. a paper on circumpolar politics or philosophy) or because they are based on archival work rather than fieldwork. It can be seen by comparing Figures 1 and 2 that some of the northern field stations are already important foci of student activity.

There are other measures of the level of student activity in the North which place this volume and the Conference upon which it was based in a broader context. The Northern Scientific Training Program now supports more than 350 students a year. The Program's definition of 'North' is indicated on Figure 1. The growth of the Program and indications of its scale, disciplinary, and regional emphases are illustrated in

et Kate McDermott, et M. Simon Okpakok, portait sur le rôle de ce Programme de l'Université McGill dans l'Arctique oriental. Actuellement, plus de cent étudiants de l'Université McGill poursuivent des études dans le cadre de ce Programme. La quasi-totalité des cours sont donnés dans l'Arctique plutôt que dans le complexe de l'Université McGill à Montréal. On peut obtenir d'autres détails en consultant les ouvrages de Wilman (1987) et Cram (1987). L'agent de liaison est Mr. David Wilman, Principal, Eastern Arctic Teacher Training Program, Iqaluit, N.W.T., X0A 0H0.

Les Voix de l'Arctique oriental. Il s'agit d'une présentation de dessins imaginatifs, de lithographies et d'objets descriptifs montés, préparés par des jeunes de l'Arctique oriental. Cette documentation constitue un exposé sur la vie culturelle des jeunes Nord-Canadiens. Cette présentation graphique a été exposée à Montréal et à Yellowknife et a fait le tour des pays scandinaves. Les éditions *Outcrop*, de Yellowknife, ont publié un ouvrage basé sur cette documentation, et rédigé par les élèves du Centre pédagogique Gordon Robertson d'Iqaluit. Voir l'ouvrage de Shapiro (1987).

Présentations graphiques des universités. Nombre d'universités ont exposé des présentations graphiques portant sur leurs programmes actuels d'Études nordiques. Ces présentations ont constitué un trait saillant de la Conférence. L'AUCEN/ACUNS a ultérieurement encouragé l'utilisation de ces présentations graphiques (et des exposés d'étudiants les accompagnant) comme cadre de la description des activités universitaires. Nous croyons que cet encouragement a déjà produit des effets positifs pour plusieurs universités.

Évaluation du progrès des Études nordiques au Canada.

Les présents Actes ne fournissent qu'une image insuffisamment détaillée d'une rencontre qui a très bien mis en relief l'envergure et l'intensité de l'engagement des intéressés dans les Études nordiques, d'un bout à l'autre du Canada. La Conférence et le contenu des Actes qui en sont issus donnent une bonne idée du niveau et de la nature des activités actuelles des universités canadiennes en matière d'Études nordiques.

Cent quatre-vingt-treize étudiants, inscrits à 33 universités, ont participé à la rencontre. On y compta 110 communications (souvent à auteurs multiples) et les Actes en reproduisent 101. La liste des participants (tableau 1) mentionne les étudiants habitant dans l'Ouest ou l'Est des T. N.-O., au Yukon, au Nouveau-Québec, au Labrador septentrional et dans les régions nordiques d'autres provinces. Certains étaient des Autochtones (Inuit, Indiens et Métis), et d'autres non. Quelques-uns de ces Nord-Canadiens étudiaient à plein temps dans les universités méridionales du Canada, d'autres dans des établissements nordiques d'enseignement (voir ci-dessus au sujet du Programme de formation des enseignants), et d'autres encore étaient inscrits à des programmes d'enseignement à distance de natures diverses. Actuellement, il n'existe pas d'université dans les territoires nordiques du Canada, mais plusieurs universités méridionales y administrent des programmes d'enseignement à temps plein, complétant ainsi les efforts du Collège de l'Arctique et du Collège du Yukon (voir *Education, Research, Information Systems and the North*, AUCEN, 1987, qui contient des exposés sur le Collège

Table 3. It will be noted that over 60% of the activity is in the Territories (47% in the NWT), the remainder in the Provincial Norths with an emphasis on northern Quebec (18%). Quebec is the Province with the largest 'Northern' territory, the largest extent of permafrost, of tundra, etc.

It is difficult to tabulate the range of topics in this volume (as a measure of the variety of current research). We have attempted, by developing clear, self explanatory titles and by means of key words, to provide readers with means of gaining an overview of topics by scanning the titles. Suffice it is to say here that the papers run the gamut of the Physical, Environmental, Health and Social Sciences and the Humanities. At risk of biassing the reader's perception, we would point out that there are papers on Inuit music, traditional medicine, mammoth bones, fossil trees, ice breaker design, archaeology, ancient caves, naturally acid and other lakes, glaciers, bogs, Inuit clothing, education, northern parks, river ice jams, various types of geology, marine science including large marine mammals, and global strategy. The papers in this volume are grouped according to the Northern Scientific Training Program's classification, Physical Sciences, Life Sciences and Human Sciences.

We would suggest that this volume, and its associated Conference, represent a revealing tip of the iceberg of Northern Studies in Canada today. The main body of the iceberg includes the hundreds of students who live and work in the North, but who are not represented here, and below them are the thousands of students who are now enrolled each year in courses which address, to a greater or lesser extent, Northern Studies topics (see "The Univerisities of Canada and the North - a Guide", *Education, Research, Information Systems and the North*, ACUNS 1987, pp. 239–362). In the body of the iceberg too are the many hundreds of university faculty (*List of Northern Specialists at Canadian Universities, Second Edition*, ACUNS 1983) who teach and conduct research in Northern Studies. This university activity includes Native Studies programs of various types, in most of ACUNS' 34 member universities (see Stonechild, B. and D. McCaskill, 1987).

The fact that, after ten years of existence, ACUNS has 34 member universities is in itself a measure of activity in Northern Studies (see Lloyd 1987).

It has been suggested that there are now more universities involved in Northern Studies in Canada than there were graduate students working in the North only two or three decades ago. While this statement might be questioned as the literal truth, it does express something of the burgeoning of academic interest which has occurred and which is still with us. However, we still have a long way to go if Canada is to take on her full responsiblities as a major polar nation. We still have a long way to go in terms of quantity of research and we have even farther to go in terms of a national focus for our research effort. Concerns about these matters are clearly expressed in Roots et al (1987). ACUNS, through for example its scholarship programs, is increasingly concerned about the quality aspect. Also, again for example, through its development of the National Student Conference on Northern Studies and its newsletter *Northline/Point Nord*, it is trying, in the universities at least, to improve the national focus and to gain some sort of overview of ongoing work so that gaps can be identified, quality assessed, and duplication minimized.

de l'Arctique, sur d'autres aspects de l'enseignement supérieur dans les T. N.-O., et sur le rôle des diverses universités dans cette région). Un nombre encore plus grand d'établissements d'enseignement supérieur sont au service des régions septentrionales des provinces, y compris certaines universités qui y sont installées (voir l'ouvrage préparé par Adams et Parker, 1987).

Le tableau 2, établi à partir *des exposés publiés dans les présents Actes*, montre la répartition de ces étudiants selon les universités, les cycles d'enseignement et les domaines d'études. Le niveau universitaire de chaque auteur-étudiant est mentionné au début de chaque exposé inclus dans les Actes. La figure 2 indique les grandes lignes de la répartition géographique des *travaux sur le terrain* dont sont issues ces communications. Chaque grande région canadienne, tant terrestre que maritime, y est représentée. Bien entendu, certaines communications ne peuvent être mentionnées sur la carte de cette façon, soit à cause de l'ampleur de leur thème (telle la philosophie ou la politique circumpolaire), ou parce qu'elles se fondent sur des travaux plus sur documents que sur le terrain. On peut voir, en comparant les figures 1 et 2, que certaines stations de terrain nordiques constituent déjà d'importants pôles d'activité pour les étudiants.

D'autres indicateurs du niveau d'activité nordique des étudiants offrent une perspective plus large sur ce niveau et sur la Conférence qui a permis de l'évaluer. Le Programme de formation scientifique dans le Nord finance maintenant les études de plus de 350 étudiants chaque année. La figure 1 montre le «Nord» tel qu'il est circonscrit pour les fins du Programme. Quant au tableau 3, il illustre le développement du Programme, son ampleur et les orientations qui lui sont données sur le plan des disciplines et des régions. Le lecteur notera que 60 pour cent de ces activités se déroulent dans les territoires (47% dans les T. N.-O) et le reste dans les régions septentrionales des provinces, et surtout au Nouveau-Québec (18%). Le Québec contient, par comparaison aux autres provinces, la plus forte proportion de terrain nordique, les plus grandes surfaces de pergélisol et de toundra, etc.

Il n'est pas aisé de classifier les diverses questions traitées dans ces Actes, afin de mieux décrire la diversité des recherches actuelles. Nous nous sommes efforcés d'élaborer des titres clairs, explicatifs, utilisant des mots-clés permettant aux lecteurs de connaître le contenu des communications par la simple lecture de la liste des titres. En résumé, disons que l'ensemble des communications touche aux domaines des sciences physiques, environnementales, sanitaires et sociales, ainsi qu'aux Lettres. Au risque de biaiser les impressions des lecteurs, soulignons que les Actes contiennent des exposés sur la musique inuit, la médecine populaire, l'archéologie, les cavernes troglodytiques, les lacs aux eaux acides naturellement ou non, les os de mammouth, les arbres fossiles, la conception des brise-glace, les tourbières, les vêtements inuit, l'enseignement, les parcs naturels du Nord, les embâcles de rivière, les diverses formations géologiques, les sciences de la mer (y compris l'étude des grands mammifères marins), et la stratégie sur le plan global. Les exposés contenus dans les présents Actes sont groupés selon la classification du Programme de formation scientifique dans le Nord, dans les sciences physiques, les sciences biologiques et les sciences humaines.

We do not wish to comment on the quality of papers in this volume - among other things because the academic level of the authors is extremely varied and the papers are not necessarily the best in the field concerned. We would acknowledge however that the quality is uneven. Also, we are conscious of gaps, or weaknesses, in the representation of some disciplines and subdisciplines. Some of these, of course, reflect the process of selection for the Conference, however others represent real weaknesses in Northern research in Canada today. We regret that, for example, law, economics, political studies and linguistics are not better represented in this volume. We also regret that some medical and engineering fields are absent. There can be various explanations of this lack of balance in the volume, many of which, of course, relate directly to the design of the Conference upon which these proceedings are based. Many of the problems of northern studies in Canada have recently been identified by Roots *et al.* (1987).

Processing of papers and organization of volume

Student contributions to the National Student Conference on Northern Studies were initially screened and accepted on the basis of abstracts and 'approval' by thesis supervisors and departmental Chairs. The written contributions were scanned and sorted by the Editors and were then distributed to those listed in Table 4 for screening and 'refereeing'. This last word is in parentheses because the Editors asked the readers to review the papers with such things as the level of the student, the stage of the work concerned (e.g. 'early progress report on thesis work') and the general interest of the paper in mind, as well as scholarly merit. Although all readers' comments were considered very seriously, the decision to publish in every case was that of the Editors who were very concerned with the concept of presenting an interesting 'sample' of Northern Studies in Canada (see discussion above). We are most grateful to the readers, thesis supervisors and others for their assistance in this process.

Acknowledgments

We are grateful to all who participated in the first National Student Conference on Northern Studies especially those who presented papers, whether they appear in this volume or not. We are particularly grateful to our colleagues, notably our student colleagues on the Organizing Committee (see Table 5). The preparations for the Conference, the Conference itself and activities resulting from the Conference, including the production of this volume, have had, are having and will continue to have a very healthy effect on Northern Studies in Canada. We believe that this will be to the longterm benefit of the country, particularly the North.

The principal sponsor of the Conference and of this volume was the Hon. Bill McKnight, Minister of Indian Affairs and Northern Development. The Conference was initiated by Mr. McKnight's predecessor, the Hon. David Crombie. Within Indian and Northern Affairs, our principal contact has been with the Circumpolar and Scientific Affairs Directorate. Without the support of Indian and Northern Affairs, the Conference would not have taken place.

Other major sponsors of the Conference were the Natural Sciences and Engineering Research Council, Health and Welfare Canada, Carleton University and the University of Ottawa. The Conference and the production of this book were organized under the aegis of the Association of Canadian Universities for Northern Studies and its 34 member universities. We are very grateful to the ACUNS Board President, Marc-Adélard Tremblay, for unwavering support under difficult financial circumstances. The Canadian Northern Studies Trust of ACUNS was particularly supportive in the development of the Conference.

Nous croyons que ces Actes et la Conférence dont ils sont issus ne montrent que le sommet de l'iceberg des Études nordiques menées actuellement au Canada. La masse non visible de ces Études est accomplie par les étudiants qui vivent et oeuvrent dans le Nord canadien, mais dont le travail n'apparaît pas dans les Actes, et par la population sous-jacente des milliers d'étudiants qui s'inscrivent chaque année à des cours concernant, de près ou de loin, des questions nordiques (voir «The Universities of Canada and the North — A Guide», dans *Education, Research, Information Systems and the North*, AUCEN, 1987, pp. 239–262). Plusieurs centaines de professeurs d'université (voir la *Liste des spécialistes du Nord dans les universités canadiennes*, 2e édition, AUCEN, 1983) enseignent et accomplissent des recherches en Études nordiques, et font partie de cette population universitaire. Les activités qu'ils mènent englobent les programmes d'Études autochtones de natures diverses mis en oeuvre par les 34 universités membres de l'AUCEN (voir l'ouvrage de Stonechild et B. et D. McCaskill, 1987).

Les dix années d'existence de l'Association de 34 universités intéressées donnent, par elles-mêmes, une bonne idée de l'ampleur des activités en Études nordiques (voir l'ouvrage de Lloyd, 1987).

Certains ont dit qu'il existe actuellement plus d'universités s'intéressant aux études nordiques qu'il n'y avait d'étudiants diplômés de 1er cycle oeuvrant il y a seulement vingt ou trente ans dans le Nord. Bien qu'on puisse discuter l'exactitude littérale de cette assertion, elle met quand même en évidence le développement prodigieux des activités universitaires pertinentes au cours de cette période, et encore maintenant. Cependant, le Canada a encore un long chemin à parcourir pour assumer la totalité de ses responsabilités de grande nation polaire. Il lui faut accroître très largement l'effort de recherches pertinent, et lui tracer un cadre national beaucoup plus ample. MM. Roots et coll. expriment clairement ces préoccupations dans leur ouvrage (1987). L'AUCEN, par le truchement de son programme de bourses, par exemple, met en évidence l'aspect qualité de ces travaux. De même l'Association s'efforce-t-elle, grâce à l'organisation d'une Conférence nationale des étudiants en Études nordiques et la publication de son Bulletin: *Point Nord/Northline*, de préciser le cadre des recherches accomplies dans les universités tout au moins, et de faire un tour d'horizon des travaux accomplis, mettant ainsi les lacunes en évidence, évaluant la qualité de l'effort accompli, et aidant à réduire les doubles emplois.

Il ne nous appartient pas de faire des remarques sur la qualité des communications reproduites dans les Actes, entre autres parce que le niveau universitaire des auteurs est fort divers, et que les exposés ne sont pas nécessairement les meilleurs dans le domaine d'études concerné. Nous reconnaîtrons cependant que cette qualité est inégale, et qu'il existe certaines lacunes ou faiblesses de la représentation de quelques disciplines ou spécialités. Certaines de ces lacunes résultent, bien entendu, du processus de choix des communications à présenter à la Conférence, mais d'autres mettent en relief des faiblesses bien réelles de la recherche nordique actuelle. Il est regrettable, par exemple, que le droit, l'économie, les études politiques ou linguistiques ne soient pas mieux représentées dans les Actes. Quelques domaines de la médecine et de l'ingénierie sont entièrement négligés. Il existe diverses explications à ce déséquilibre des

The Hon. Bill McKnight, through Professor T.H.B. Symons (Chair) and the Northern Science Award Committee kindly and imaginatively invited the Conference delegates to the reception and ceremony at which the 1986 Award was presented.

The Editors, and the Organizing Committee, gratefully acknowledge the many contributions of Eileen van Heyst, Administrative Officer of ACUNS, at all stages of the project. Without her help, the outcome would have been very different indeed.

Peter Adams
ACUNS and Trent University, Peterborough, Ontario
Peter Johnson,
University of Ottawa, Ottawa, Ontario

References

Adams, W.P. 1987. "Field facilities in arctic and subarctic Canada", Education, Research, Information Systems and the North (W.P. Adams, ed.), ACUNS, pp. 49–54.

Adams, W.P. (in press). "Bases for field research in arctic and subarctic Canada", Arctic.

Adams, W.P. and D. Parker (eds) 1987. Canada's Subarctic Universities/Les universités canadiennes du moyen-nord, ACUNS, Ottawa 282 p.

Bielawski, E., 1987. "The Northern Heritage Society: a case study in developing science with northerners", Education, Research, Information Systems and the North (W.P. Adams, ed.), ACUNS, pp. 28–31.

Campbell, G., W.P. Adams and H. Finkler, 1987. Canada's Northern Stations, ACUNS, 44 p.

Cram, Jack 1987. "Northern teachers for northern schools: an Inuit teacher-training program", Education, Research, Information Systems and the North (W.P. Adams, ed.), ACUNS, pp. 116–123.

Finkler, H.W. 1987a. "The Northern Scientific Training Program: a program to support university development of scientific expertise in Canada's North", Education, Research, Information Systems and the North (W.P. Adams, ed.), ACUNS, pp. 66–72.

Finkler, H.W. 1987b. Northern Scientific Training Program Annual Report 1986-87/Programme de formation scientifique dans le Nord, Rapport Annuel 1986-87, Department of Indian Affairs and Northern Development, Ottawa K1A 0H4.

Higgins, R. 1987 "The Inuit Tapirisat of Canada: bridging the gap, the need for new approaches to northern research and education" Education, Research, Information Systems and the North (W.P. Adams, ed.), ACUNS, pp. 36–38.

Lloyd, T. 1987. "Whence came ACUNS?" In: Proceedings, 10th Anniversary Conference of ACUNS, in press.

Roots, E.F., W.P. Adams, P. Burnet and M. Gordon 1987. Canada and Polar Science/Le Canada et la science polaire, Department of Indian and Northern Affairs, Canada, 117 p.

Shapiro, Jane Ann (ed.) 1987. Voices from the Eastern Arctic, Outcrop, Box 1356, Yellowknife, N.W.T.

Stonechild, B. and D. McCaskill 1987. The development of Indian/Native Studies in Canada, Education, Research, Information Systems and the North (W.P. Adams, ed.), ACUNS, pp. 103–108.

Wilman, David 1987. "Teacher training in the Canadian Eastern Arctic", Education, Research, Information Systems and the North (W.P. Adams, ed.), ACUNS, pp. 123–126.

Actes, dont certaines touchent à la conception même de la Conférence dont il est issu. Roots et coll., dans leur ouvrage (1987), ont mis en évidence de nombreux problèmes qui affectent les Études nordiques au Canada.

Processus de choix des communications et plan des Actes

Les contributions à la Conférence nationale des étudiants en Etudes nordiques ont été, en premier lieu, choisies et acceptées en fonction de leur résumé analytique et de l'«approbation» des directeurs de thèse et des directeurs du département universitaire. Les communications écrites ont été lues et choisies par les directeurs de publication, puis réparties entre les évaluateurs (dont la liste figure au tableau 4) chargés du choix et de l'«approbation» des communications. Le mot ci-dessus se trouve entre parenthèses parce que consigne avait été donnée aux évaluateurs de lire chaque communication en tenant compte, par exemple, du niveau universitaire de l'auteur-étudiant, de l'étape atteinte par ses recherches (par exemple s'il s'agissait d'un premier rapport d'avancement des travaux d'une thèse), de l'intérêt général de la communication, autant que de sa qualité intellectuelle. Bien que les observations des évaluateurs aient été sérieusement prises en considération, ce sont les directeurs de publication qui ont assumé la décision finale dans chaque cas, car ils étaient très désireux de présenter un «échantillon» intéressant des études nordiques au Canada (voir le débat précédent). Nous remercions de tout coeur les évaluateurs, les directeurs de thèse et les autres personnes qui nous ont accordé leur aide au cours de ce choix.

Remerciements

Nous remercions tous les participants à la Conférence nationale des étudiants en Études nordiques, et particulièrement ceux qui ont présenté des communications, qu'elles soient ou non reproduites dans les Actes. Nous sommes particulièrement reconnaissants envers nos collègues, et spécialement nos collègues étudiants du Comité d'organisation (voir le tableau 5). La préparation de la Conférence, sa réunion et les activités qui en ont découlé, y compris l'élaboration des présents Actes, ont eu et continueront à avoir des effets favorables sur les Études nordiques au Canada. Nous estimons qu'ils procureront encore à long terme des avantages pour notre pays, et particulièrement pour le Nord.

C'est l'Honorable Bill McKnight, Ministre des Affaires indiennes et du Nord, qui a été le principal parrain de la Conférence et soutien de la publication des Actes. La Conférence avait été lancée tout d'abord par l'honorable David Crombie, prédécesseur de M. McKnight. C'est au sein de la Direction générale des Affaires circumpolaires et scientifiques que se trouvait notre principal agent de liaison. La Conférence n'aurait pu avoir lieu sans le soutien du Ministère des Affaires indiennes et du Nord.

Parmi les autres parrains directs de la Conférence, mentionnons le Conseil de recherches en sciences naturelles et en génie, Santé et Bien-être social Canada, Carleton University et l'Université d'Ottawa. C'est sous les auspices de l'Association universitaire canadienne d'Études nordiques et ses 34 universités membres qu'on a mis la Conférence sur pied et élaboré les présents Actes. Nous remercions vivement M. Marc-Adélard Tremblay, Président du conseil d'administration de l'AUCEN, dont le soutien inébranlable nous a permis de surmonter les difficultés financières. La Fiduciaire canadienne d'Études nordiques a fourni une aide particulièrement utile lors de la mise sur pied de la Conférence. C'est l'honorable Bill McKnight qui, par le truchement de M. T.H.B. Symons (président) et du Comité du Prix de la recherche scientifique sur le Nord, a aimablement invité, de façon imaginative, les participants à la réception et à l'attribution de ce Prix pour 1986.

Les directeurs de publication et le Comité d'organisation remercient de tout coeur Mme Eileen van Heyst, agente d'administration de l'AUCEN, pour sa contribution infatigable à toutes les étapes de l'entreprise. Sans son aide, les résultats auraient été bien différents.

Peter Adams
AUCEN et l'Université Trent, Peterborough (Ontario)
Peter Johnson,
l'Université d'Ottawa, Ottawa (Ontario)

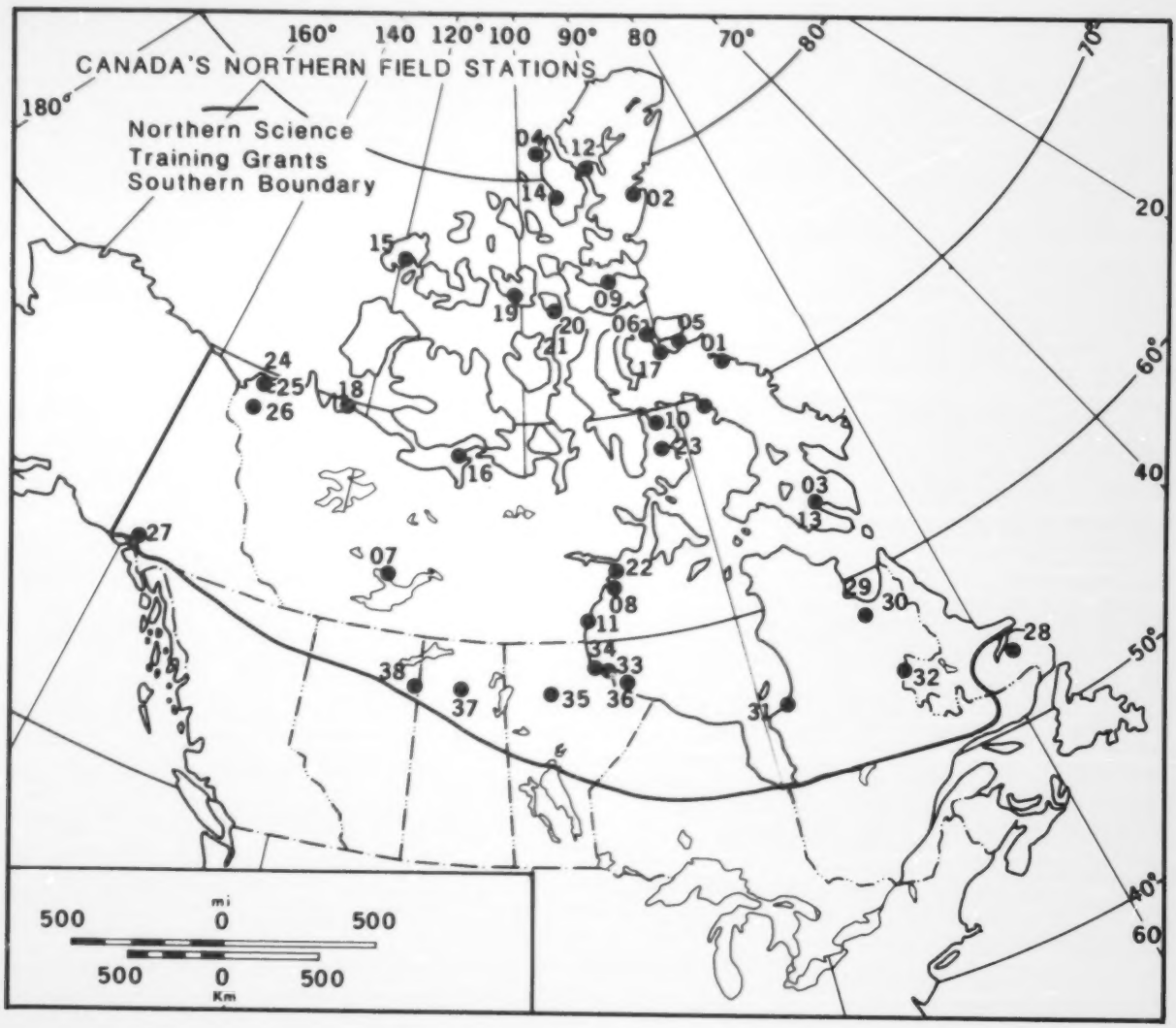


Figure 1. Canada's Northern Field Stations

NORTHWEST TERRITORIES

1. Adams Island, 71N, 73W
2. Alexandra Fiord Post (R.C.M.P.), 79N, 76W
3. Arctic Biological Station — Field Camp, 64N, 69W
4. Arctic Ice Island (PCSP), 81N, 97W (moving)
5. Arctic Research Establishment, 73N, 78W
6. Borden Station, 74N, 82W
7. Chitty Lake Field Station, 61N, 114W
8. Coates Island, 63N, 83W
9. Devon Island Research Station, 76N, 85W
10. Eastern Arctic Scientific Resource Centre, 69N, 82W
11. Eskimo Point Arctic Research Centre, 61N, 94W
12. Eureka Aerological Station, 80N, 86W
13. Ikaluit Research Laboratory, 64N, 69W
14. McGill Axel Heiberg Station, 79N, 91W
15. Mould Bay Aerological Station, 76N, 119W
16. Nauyuk Lake Field Station, 68N, 108W
17. Nunguvik Arctic Centennial Station, 72N, 81W
18. Pearce Point Field Station 70N, 123W
19. Polar Bear Pass High Arctic Research Stn., 76N, 98W
20. Resolute Bay Field Station, 75N, 95W
21. Resolute Station (PCSP) 75N, 95W
22. Saqvaqjuac Field Station, 64N, 91W
23. Sarcpa Lake Field Station, 69N, 83W
24. Tuktoyaktuk Field Station, 69N, 133W
25. Tuktoyaktuk Station (PCSP), 69N, 133W
26. Western Arctic Scientific Resource Ctre, 68N, 134W

YUKON TERRITORY

27. Kluane Lake Research Station, 61N, 139W

NEWFOUNDLAND/LABRADOR

28. Labrador Institute of Northern Studies, 53N, 60W

QUÉBEC

29. Kuujjuaq Research Centre, 58N, 68W
30. Kuujjuaq Research Station, 58N, 68W
31. Kuujjuarapik Research Station, 55N, 78W
32. McGill Subarctic Research Station, 55N, 67W

MANITOBA

33. Churchill Northern Studies Centre, 58N, 94W
34. Institute of Arctic Ecophysiology, 58N, 94W
35. Southern Indian Lake Research Station, 56N, 98W
36. Tundra Biological Station, 59N, 93W

SASKATCHEWAN

37. Cree Lake Aerological Station, 57N, 107W

ALBERTA

38. Mildred Lake Environmental Research Camp, 57N 111W

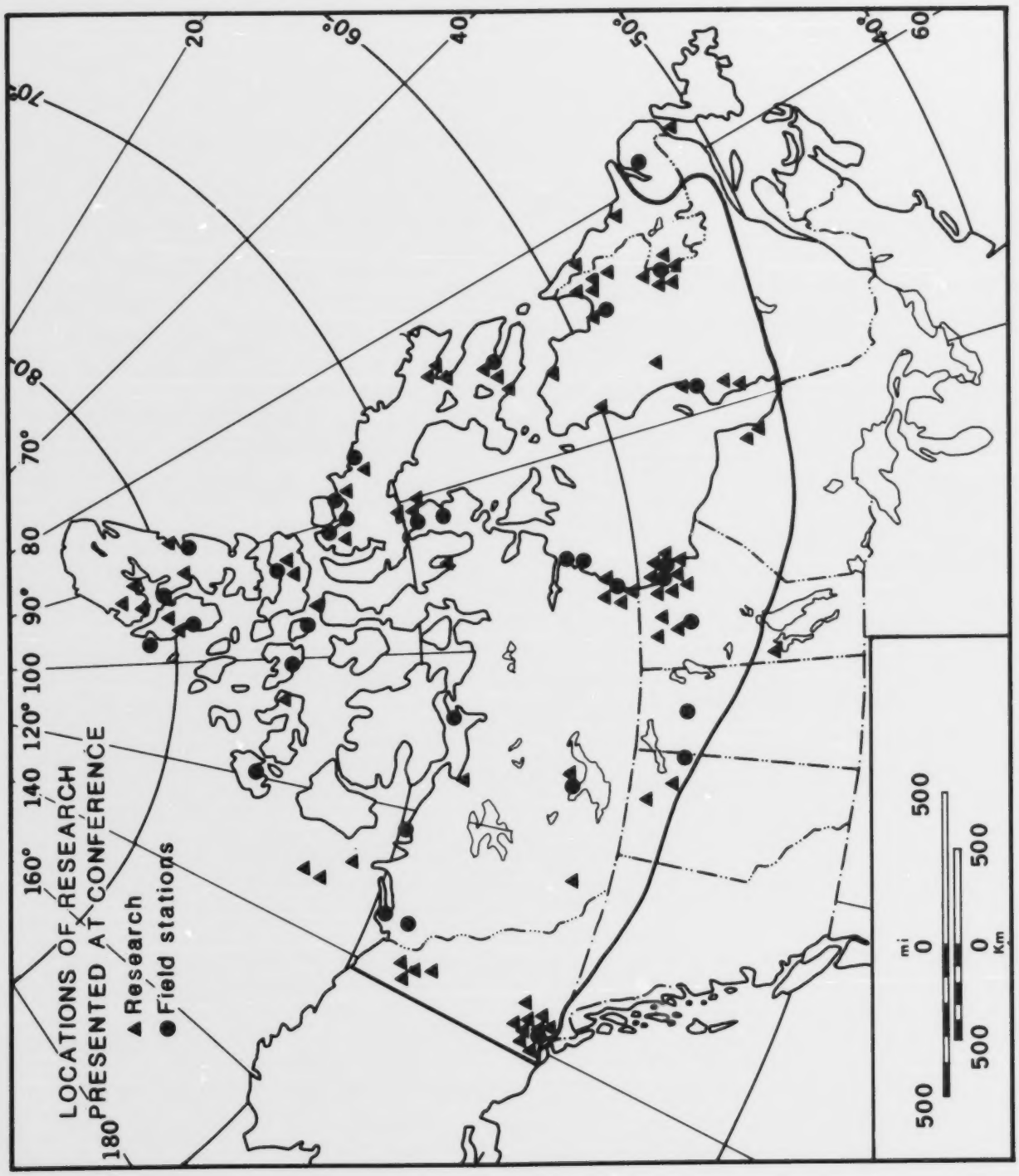


Figure 2. Locations of Research Presented at Conference

TABLE 1
National Student Conference, November, 1986
Participants
(* - non-student)

Name	Department	University or Affiliation
Peter Adams		ACUNS/AUCEN and Trent University*
Rebecca Aird	Envir. Studies	York University
Don Albright	Renewable Resources	McGill (Macdonald College)
Valerie Alia	Anthropology	York University
Craig Allan	Geography	Trent University
Thomas Alogut		Confederation College, Ottawa
Malachi Arreak		Confederation College, Ottawa
Reginald Auger	Archaeology	University of Calgary
Michel Barbeau	Études régionales	Université du Québec à Chicoutimi
Claire Barnabé		Indian & Northern Affairs Canada*
Jennifer Bates	Geology	Dalhousie University
Ken Beardsall	Geog./Native Studies	Trent University
Margaret Beaton	Biology	University of Windsor
Luc Beaudry	Géographie	Université d'Ottawa
Jean-Marie Beaulieu	Environ. Studies	York University
Patricia Becker	Environ. Studies	York University
Céline Belzile	Environ. Studies	York University
John Bennett		Carleton University
Lorne Bennett	Geology	University of Ottawa
Cathy Bentley	Forestry	University of Toronto
Jean-François Bergeron	Plant Ecology	University of Toronto
Denyse Bilodeau	Anthropologie	Université Laval
Marc Boileau	Biology	University of Windsor
Tom Boivin	Biology	University of Waterloo
Guy Brassard	Biology	Memorial University*
Lynn Brodsky	Ecology	Queen's University*
Paul Budkewitsch	Sc. de la Terre	Université du Québec à Montréal
Barry Cameron	Geology	Dalhousie University
Ian Campbell	Geology	University of Ottawa
Wayne Cardwell	Geography	Ryerson Polytechnical Institute
James B. Carefoot	Extension Dept.	University of Regina*
Brenda Celi	Zoology	University of Guelph
Allan Chapman	Hydrology	Trent University
Oksana Choulik	Limnology	Trent University
Cecile Clayton	Human Ecology	University of Manitoba
Adrienne Clements	Envir. Studies	York University
Leslie Cole	Geography	University of Ottawa
Paula Conlon	Music	Université de Montréal
John Crump		Carleton University
Janis Dale	Geomorphology	Queen's University
Leah d'Argencourt		Vanier, Ontario*
Madeleine d'Argencourt		Merivale High School & Northern Heritage Society
Ian Darragh		Royal Canadian Geographical Society*
Cindy De Cuypere	Geography	Carleton University
Kenneth de la Barre	Geography	McGill University
Daniel Desrochers	Geography	McGill University
Louise Desrochers	Biology	Université du Québec à Montréal
Véronique Dewez	Géomorphologie	Université d'Ottawa
Marisa Ditata	Géographie	McGill University
D.W. Doidge	Zoology	McGill University
Janice Donovan		Sarsfield, Ont.*
Peter Doran	Geography	Queen's University
Nancy Doubleday		Inuit Tapirisat of Canada*
Marianne Douglas	Biology	Queen's University
Frank Duerden	Geography	Ryerson Polytechnical Institute*
Rose Dufour	Anthropologie	Université Laval
P.M. Dwyer	Biology	Laurentian University
Miles Ecclestone	Watershed Ecosystems	Trent University
Jack Ellis	Envir. Studies	York University*
Francis Falardeau	Géologie struct.	Université du Québec à Montréal
Marta Fasiolo	Educational Linguistics	Concordia University
Harald Finkler		Indian and Northern Affairs Canada*
Allison Fleury	Geography	Ryerson Polytechnical Institute
Violet Ford		Mount Saint Vincent University
Robert Fortin	Gestion et géographie	Université du Québec à Hull
Michel Frédérick	Sc. Politique	Université Laval
Max Friesen	Archaeology	University of Toronto
Claude Gagnon	Anthropologie	Université Laval
Jean Y. Gagnon	Biology	Queen's University
Jacques Gérin		Indian & Northern Affairs Canada*
John Glew	Geography	Queen's University
Peter Graham	Geography	University of Toronto
Keith Greenaway		Ottawa, Ontario*
David Gregory	Nursing	University of Manitoba
Paul Grigoriew	Regional Planning	University of Waterloo
Joachim Haertling	Geography	Queen's University
Michael Hall	Mammalogy	Laurentian University
Louis-Edmond Hamelin		Université Laval*
Tom Hammond	Geography	University of Waterloo
Stephen Hansen	Biology	Laurentian University
Kenneth Hare	Geography	University of Toronto*
Gordon Hart	Botany	University of Toronto
Lois Harwood	Zoology	University of Alberta
Carolyn Hawley		Nunavut Constitutional Forum*
Tom Haythornthwaite	Geography	Carleton University
Judy Head	Native Studies	University of Saskatchewan
Terry Hedderson	Botany (Bryology)	Memorial University
Fred Helleiner	Geography	Trent University*
Luise Hermanutz	Plant Science	University of Western Ontario
Andrew Heyes	Geography	University of Western Ontario
David Hik	Botany	University of Toronto
Norah Hillary	Geography/Env. Sci.	Trent University
Barry Hochstein	Political Science	University of Calgary
Steve Hornsby	Geography	Ryerson Polytechnical Institute
Paul Huneault	Génie civil	École Polytechnique
Peter Hutchinson	Geography	Trent University
Paul Idle	Biology	Laurentian University
Alootook Ipellie		Inuit Circumpolar Conference*
Rhoda Innuksuk		Inuit Tapirisat of Canada*
Monica Ittusardjuat	EATEP, Iqaluit	McGill University
Maureen Jedynack	Geography	University of Ottawa
Robert L. Jeffries	Botany	University of Toronto*
J. Peter Johnson	Geography	Carleton University*
Martha Johnson	Anthropology	University of Toronto
Peter G. Johnson	Geography	University of Ottawa*
Jennifer Kasper	Geography	University of Ottawa

Name	Department	University or Affiliation
Peter Kelly	Geography	University of Western Ontario
Michèle Kerisit	Anthropology	University of Ottawa
Chris Kingsbury	Geography	McGill University
Leah Kongsrude	Biogeography	York University
Peter Kotanen	Ecology	University of Toronto
William Kymlicka	Philosophy	Queen's University
Yves Labrèche	Anthropologie	Université de Montréal
Diane Lacasse	Géographie	Université d'Ottawa
Stuart Lane	Political Science	Queen's University
Bernard Lauriol	Géographie	Université d'Ottawa
John Legg		Energy, Mines & Resources Canada*
Serge Lepage	Océanographie	McGill University
Marco Levasseur	Démographie	Université de Montréal
Martin Lewis	Biology	York University*
Patricia Lewis	Zoology	University of Ottawa
Jocelyn Lillycrop		Natural Sciences & Engineering Research Council, Ottawa*
Olav Loken		Indian & Northern Affairs Canada*
Bruce Lourie	Envir. Studies	York University
Keith Lowther	History	Trent University
Marianne Lykke Thomsen	Northern Studies	McGill University
Shona MacLachlan	Envir. Studies	York University
Allen Maghagak		Nunavut Constitutional Forum*
Claire Mailhot	Cdn. Studies	Carleton University
Frank Mallory	Biology	Laurentian University*
Paul Mathers	Biology/Env. Sci.	Trent University
Lin Maus	Geography	University of Windsor
Barry McArthur	Geography	Trent University
Sheri McBride	Clothing & Textiles	University of Manitoba
Kate McDermott	EATEP, Iqaluit	McGill University
Sharon McGee	Envir. Science	Trent University
Shirley McGrath	Bus. Admin.	University of New Brunswick
Virginia McIntyre		University of Ottawa
Elisabeth McIver	Paleobotany	University of Saskatchewan
John McMahon	Northern Studies	Carleton University
Amy McNulty	Botany	University of Toronto
David McRobert	Environ. Law	York University
Yves Michaud	Géomorphologie	Queen's University
Joan Montagnes	Biology	University of Toronto
Kelley Monument	Geography	Ryerson Polytechnical Institute
Brian Moorman	Geography	Carleton University
Joan Moulton	Geography	Memorial University
Clara Murphy	Folklore	Memorial University
Peter Murphy	Geography	Carleton University
Sheilagh Murphy	Geography	University of British Columbia
Andrew Nadeau	Geography	McGill University
Phoebe Nahanni	Geography	McGill University
Valeri Nalivalkine		U.S.S.R. Embassy*
Kim Naqvi	Geography	Wildrid Laurier University
Vital Navya		Confederation College
Wendy Neander	Nursing	University of Alberta
Sue Neil	Anthropology	Trent University
Gordon Nelson	Geography	University of Waterloo*
David Neufeld	Environ. Planning	University of Waterloo
Jill Oakes	Clothing/Textiles	University of Manitoba
Ted Oakes	Ecology	Queen's University
Caroline Oblin	Social Work	McGill University
Carey Ogilvie	Biology/Ecology	York University
Simon Okpakok	EATEP, Iqaluit	McGill University
Marcel Ouellet	INRS-Eau	Université du Québec*
Robert Palmer	Oceanography	Dalhousie University
Robert Park	Archaeology	University of Alberta
Bruce Paterson	Ocean Engineering	Memorial University
Donna Pawlowski	Envir. Studies	York University
Andrew Pellizzari	Botany	University of Toronto
Bella Petawabano		McGill University
John Petrolias		Indian and Northern Affairs Canada*
Claudine Picard	Géographie	Université d'Ottawa
Jon Pierce	Canadian Studies	University of Ottawa
Jonathan Price	Geography	McMaster University
Thomas Rahn	Botany	University of Toronto
Martin Raillard	Plant Ecology	University of Toronto
Rick Riewe	Zoology	University of Manitoba & T.F.N.*
K. Robertson	Biology/Ecology	York University
Jon Rose	Political Studies	Queen's University
Diane Rowley	Northern & Native St.	Carleton University*
Graham Rowley	Canadian Studies	Carleton University*
Alain Roy	Géographie	Université d'Ottawa
Floyd Rudmin	Psychology	Queen's University
Diom Saganash	Sces. Juridiques	Université du Québec en Abitibi-Témiscamingue
Robert Sauvé	Développement régional	Université du Québec en Abitibi-Témiscamingue
Donat Savoie		Indian & Northern Affairs Canada*
Margaret Scopick	Anthropology	Carleton University
Peter Scott	Zoology	University of Toronto
Jane Ann Shapiro		Montreal*
Len Sillanpaa		Indian & Northern Affairs Canada*
Sarah Silou	Northern & Native St.	Carleton University
Mark Simpson	Ecology	University of Alberta
Valerie Sloan	Geography	Trent University
Scott Slocombe	Urb. & Reg. Planning	University of Waterloo
Chris Smit	Geography	Ryerson Polytechnical Institute
James David Smith	Geography	York University
Nicolas St. Cyr	Géomorphologie	Université Laval
Bruce Stadfeld	History	Brandon University
John Stager	Geography	University of British Columbia*
Janet Stavinga	Geography	McGill University
Becky Stemper	Geology	University of Toronto
Douglas Stenton	Anthropology	University of Alberta
Lisa Stephenson	Biology	Queen's University
Klaas Stoker	Geography	Carleton University
Josef Svoboda	Botany	University of Toronto*
Trevor Swerdfager	Geography	University of Ottawa
Sarah Tautuajuk		Iqaluit, N.W.T.*
Pierre Thibaudeau	Géomorphologie	Université Laval
Marc-Adélard Tremblay	Anthropologie	President, ACUNS; Université Laval*
Emily Tutanuak	Education	McGill University
Kim Underwood	Environ. Studies	York University
Lorraine Wakely	Mammalogy	Laurentian University
Marilyn Walker	Anthropology	York University
Xiacheng Wang	Geology	University of Ottawa
Debbie Webster		Merivale High School & Northern Heritage Society
Shelley Watson	Watershed Ecosystems	Trent University
Sue Watson	Environ. Science	Trent University
Andrew Webster	Geography	Trent University
Christoph Wels	Watershed Ecosystems	Trent University
Stephen Wolfe	Geography	Carleton University
Ellen Woodley	Plant Ecology	University of Toronto

Name	Department	University or Affiliation	Name	Department	University or Affiliation
Douglas West	Political Science	Carleton University	Robert Young	Geography	University of Western Ontario
Debra Wright	Canadian Studies	Carleton University			
Wanda Wuttunee	Management	University of Calgary	Steven Young	Metall. Engineering	University of Alberta
Kathy Young	Geography	University of Toronto	Suzanne Young	Geography	University of Waterloo

TABLE 2
Analysis of Papers

UNIVERSITY	NUMBER OF PAPERS	SCIENTIFIC FIELD			ACADEMIC LEVEL			N.W.T.	YUKON	ALTA.	MAN.	ONT.	QUE.	LABRADOR	NO SPECIFIC AREA
		PHYSICAL SCIENCES	LIFE SCIENCES	HUMAN SCIENCES	PH.D	MASTER'S	UNDERGRAD.								
University of Alberta	6	1	3	2	2	3	1	4	1	1					
Brandon University	1			1			1				1				
University of British Columbia	1			1		1			1						
University of Calgary	2			2	1	1		1						1	
Carleton University	5	2	1	2	1	3	1	3					1		1
Concordia University	1			1			1	1							
Dalhousie University	3	3				2	1	3							
Laurentian University	4		4			4		2			2				
Université Laval	4			4	3	1		1					1		2
University of Manitoba	5		2	3	2	3		3		1	1				
McGill University	4	4			1	2	1	1					3		
McMaster University	1		1		1							1			
Memorial University	5	3	1	1		5		1	1					2	1
Université de Montréal	2			2	2			1					1		
Mount Saint Vincent University	1			1			1							1	
University of New Brunswick	1			1			1	1							
University of Ottawa	9	8	1		3	5	1	1	7				1		
Université du Québec à Chicoutimi	1			1		1							1		
Université du Québec à Montréal	2	2				1	1						2		
Université du Québec en Abitibi-Temiscamingue	1			1			1						1		
Queen's University	5	3		2	4		1	2				1	2		
University of Saskatchewan	2		1	1	1		1	1			1				
University of Toronto	10		8	2	2	8		2	1		6		1		
Trent University	8	2	4	2		5	3	5	1		1		1		
University of Waterloo	3	1	1	1		2	1	1					1		1
University of Western Ontario	1	1				1		1							
University of Windsor	2		2		1	1		1			1				
York University	8	1	5	2	1	7		4	3		1				
Other	1			1	N/A			1							
TOTAL	99	31	34	34	25	56	17	41	15	2	14	2	16	4	5

TABLE 3
Measures of activity of the Northern Scientific Training Program of Indian and Northern Affairs Canada
(from Finkler 1987b)

TABLE 3a
Distribution of Northern Scientific Training Funds by Number of Students Supported, Allocations per Student, Number of Days per Student in the North, and Cost per Student/Day in the North, 1982-83 to 1986-87

YEAR	TOTAL FUNDS ALLOCATED	TOTAL FUNDS SPENT/ COMMITTED	TOTAL NUMBER OF STUDENTS SUPPORTED	AVERAGE FUNDS ALLOCATED PER STUDENT	AVERAGE NUMBER OF DAYS PER STUDENT IN THE NORTH	AVERAGE COST PER STUDENT/ DAY IN THE NORTH
1982-83	$625,000	$618,477.87	285	$2,170.09	51.3	$42.30
1983-84	725,000	745,979.79	317	2,343.25	52.6	44.74
1984-85	825,000	783,955.62	295	2,657.48	52.7	50.43
1985-86	825,000	838,283.01	348	2,408.85	51.3	46.95
1986-87	825,000	808,862.42	366	2,210.00	48.8	45.28

TABLE 3b
Distribution of Students Supported by Northern Scientific Training Program by Scientific Field, 1982-83 to 1986-87

		SCIENTIFIC FIELD				
YEAR		PHYSICAL SCIENCES	LIFE SCIENCES	HUMAN SCIENCES	OTHER	TOTAL NUMBER OF STUDENTS
1982-83	N	89	104	78	14	285
	%	31.2	36.5	27.4	4.9	
1983-84	N	94	119	97	7	317
	%	29.6	37.5	30.6	2.2	
1984-85	N	87	123	83	2	295
	%	29.5	41.7	28.1	0.7	
1985-86	N	108	135	49	6	348
	%	31.0	38.7	28.4	1.7	
1986-87	N	123	143	97	3	366
	%	33.6	39.0	26.5	0.8	

TABLE 3c
Distribution of Northern Scientific Training Funds by Geographical Focus, 1983-84 to 1986-87

	GEOGRAPHIC FOCUS					
YEAR	NORTHWEST TERRITORIES	YUKON	LABRADOR	NORTHERN QUEBEC	OTHER*	TOTAL FUNDS SPENT
1983-84	$302,913.75	$103,150.57	$39,940.00	$167,994.00	$131,981.47	$745,979.79
	% 40.6	13.8	5.4	22.5	17.7	
1984-85	319,963.71	122,407.00	44,554.95	146,847.90	150,181.96	783,955.62
	% 40.8	15.6	5.7	18.7	19.1	
1985-86	371,708.16	131,247.98	35,709.00	154,571.76	145,046.61	838,283.01
	% 44.3	15.6	4.2	18.4	17.3	
1986-87	377,684.43	119,572.97	50,100.00	145,068.00	116,437.01	808,862.42
	% 46.6	14.7	6.1	17.9	14.3	

*Other category also included expenses incurred for projects undertaken in other circumpolar regions. Such allocations were discontinued after 1983-84 as a result of NSTP Committee revisions to Program Guidelines.

TABLE 3d
Distribution of Northern Scientific Training Funds by University, 1986 (adapted from Finkler, 1987b)

UNIVERSITY	TOTAL NUMBER OF STUDENTS SUPPORTED	SCIENTIFIC FIELD				AVERAGE NO. OF DAYS PER STUDENT IN THE NORTH	AVERAGE COST PER STUDENT/DAY IN THE NORTH				
		PHYSICAL SCIENCES	LIFE SCIENCES	HUMAN SCIENCES	OTHER			UNDERGRADUATE	MASTER'S	DOCTORAL	OTHER
University of Alberta	24	13	4	7	0	59.0	$39.90	5	12	7	0
University of British Columbia	4	1	3	0	0	124.0	30.34	1	3	0	0
University of Calgary	18	7	4	7	0	52.4	38.33	9	7	2	0
Carleton University	28	14	0	14	0	38.2	47.76	17	9	2	0
Concordia University	2	0	0	2	0	15.0	69.82	1	1	0	0
University of Guelph	8	1	6	1	0	71.1	18.27	4	3	1	0
Lakehead University	6	0	0	6	0	24.1	67.27	5	1	0	0
Université Laval	22	9	11	2	0	53.5	51.82	6	7	9	0
University of Manitoba	7	0	4	2	1	91.4	37.31	0	6	1	0
McGill University	28	13	7	8	0	48.6	44.11	12	10	6	0
McMaster University	7	7	0	0	0	53.4	52.03	1	3	3	0
Memorial University	20	10	6	4	0	46.4	42.24	10	8	2	0
Université de Montréal	17	5	3	7	2	30.0	71.96	5	9	3	0
University of New Brunswick	4	1	3	0	0	85.0	25.03	2	1	1	0
University of Ottawa	10	7	2	1	0	36.6	71.00	1	7	2	0
Université du Québec à Montréal	3	2	0	1	0	55.0	47.27	1	1	1	0
Queen's University	39	9	27	3	0	41.1	29.40	24	8	7	0
Ryerson Polytechnical Institute	11	3	6	1	1	46.3	51.92	11	0	0	0
University of Saskatchewan	11	3	0	3	3	56.1	49.79	2	5	4	0
Simon Fraser University	4	0	2	2	0	54.2	44.10	0	4	0	0
University of Toronto	24	5	16	3	0	49.1	47.13	10	10	4	0
Trent University	11	6	1	4	0	51.8	39.48	7	4	0	0
University of Waterloo	18	2	8	8	0	46.1	48.20	4	9	5	0
University of Western Ontario	9	6	2	1	0	39.3	59.55	3	4	2	0
University of Windsor	10	3	6	1	0	40.9	70.96	6	3	1	0
York University	21	2	14	5	0	49.7	44.01	3	16	2	0
TOTAL N	366	123	143	97	3	48.8	45.28	150	151	65	0
%		33.6	39.0	26.5	0.8			40.9	41.2	17.7	0.0

TABLE 4
List of readers who processed papers

Professor W. Barr, University of Saskatchewan
Professor A. Brunger, Trent University
Mr. Peter Burnet, Indian & Northern Affairs Canada
Professor J. Buttle, Trent University
Professor O. Dixon, University of Ottawa
Professor J. Dufour, Université du Québec à Chicoutimi
Professor R. Edwards, Trent University
Professor J. Fenwick, University of Ottawa
Professor M. Guerts, University of Ottawa
Professor J. Guilbault, University of Ottawa
Professor F. Helleiner, Trent University
Professor H. Helmuth, Trent University
Professor R. Heron, Carleton University
Professor P. Howarth, University of Waterloo
Professor P. Johnson, University of Ottawa
Professor R. Jones, Trent University
Professor D. Lasenby, Trent University
Professor S. Lockhart, Trent University
Professor F. Mallory, Laurentian University
Professor J. Marsh, Trent University
Professor J. McNeill, University of Ottawa
Professor R. Needham, University of Ottawa
Professor G. Nelson, University of Waterloo
Professor J. Nighswander, Trent University
Dr. D. St. Onge, Geological Survey of Canada
Dr. P. Schledermann, University of Victoria
Mr. A. Sneyd, Canarctic Shipping Co. Ltd.
Professor J. Theberge, University of Waterloo
Professor M.-A. Tremblay, Université Laval
Dr. J-S. Vincent, Geological Survey of Canada

TABLE 5
Organizing committee/comité d'organisation

Dr. P.G. Johnson, University of Ottawa (Chairman)
Dr. R.D. Needham, University of Ottawa (Co-Chairman)
Dr. W.P. Adams, ACUNS and Trent University
Jennifer Kasper, University of Ottawa
Diane Lacasse, University of Ottawa
Claire Mailhot, Carleton University
Brian Moorman, Carleton University
Peter Murphy, Carleton University
Alain Roy, University of Ottawa
Marg. Scopick, Carleton University
Sarah Silou, Carleton University
Eileen van Heyst, ACUNS
Doug West, Carleton University
Stephen Wolfe, Carleton University

ÉLÉMENTS D'UNE NORDOLOGIE — A SCIENCE OF THE NORTH AN ADDRESS TO THE NATIONAL STUDENT CONFERENCE ON NORTHERN STUDIES

Louis-Edmond Hamelin, professeur émérite, Université Laval,
Recipient of the Centenary Medal for Northern Science, 1986

Monsieur le Président Marc-Adélard Tremblay, AUCEN/ACUNS
Membres du Comité d'organisation du colloque,
Chers et chères collègues

It is a great joy for me to participate in this national meeting with so many dedicated students of our still partly unknown Canadian North. The few of us who were present at Saskatoon in 1967 when the Northern Science Training Conferences were initiated (from which ACUNS/AUCEN emerged), never envisaged the high standard and level of participation of this conference. Best wishes to all of you and congratulations to those responsible for its success.

I would like to present to you my idea of the North: how it happens that I have a specific approach to it and to whom I am indebted. Did I build it step by step? In fact, there was and is a close relation between my way of thinking and my way of viewing the North.

I — Northern concepts and career

My own *nordicity* has developed from four types of sources. First, I had the privilege of attending the McGill Summer School in 1947 and 1948. Four professors gave courses on polar lands, among them the famous explorer, Vilhjamur Stefansson, and scientists like Kenneth Hare (who will also be speaking at your conference). For the first time, I learned about the North. McGill contributed to changing the course of my life and since then I have tried to become northern-minded. The second strategy of my nordication was to go in the field many times. In 1948, I made two trips, one by canoe, one by small plane, to the James Bay area to assess, as a young economist, the possibilities for local development. Since then, I have travelled in the circumpolar world as far as the Aldan River in Eastern Siberia to the Yukon River in Alaska.

Thirdly, concerning the North, I was and am an autodidact, for my main objective is still to understand a region, a geographic area, where many things are integrated and are closely linked. Such a program was and is barely taught; you cannot get it by studying one or two disciplines, like botany and epidemiology. The usual approach to any northern problem is still the disciplinary approach; that, I was not searching for. Consequently, I tried to catch, by myself, some *nordism*, at my own risk, by reading extensively and discussing with northern peoples on one hand, and scholars (e.g. at the Scott Polar Research Institute) on the other. How far I went on that quite isolated road I do not know. Finally, my conception of the North has benefitted from freethinking on problems and situations. The best chance I had was getting a seat in the NWT Legislative Assembly at Yellowknife. So, there are my four ways and means of becoming a northerner or northist.

Now, I should like to try to characterize that nordology. You will discover some close links with what I have already said. Stefansson, "the old Stef", had taught me two things: "There are two kinds of northern problems: the imaginary and the real; of the two, the imaginary are the more important, for man finds it easier to change the face of nature than to change his own mind"[1]. Even if that sentence could be interpreted partly as a joke, I have received it as a fundamental message. I was and am convinced that there are two kinds of North: a real North, an example of which was the discovery of islands by Stefansson himself. To see things and peoples just as they are, we have to go North as many times as we can. The real North is located "up there" and not much inside our southern universities. A great part of that real North is known today. But there is the other type of North, the mental North, of which many varieties remain very unknown. How many of us understand completely what an Inuit means when saying: "the white bear is my culture" or when a Dene asserts: "land has a soul"? Let me add that the idea of the North of so many southern Canadians is very undocumented. On that matter, Kenneth Hare wrote (1972): "Canadians have not, as a nation, put the North anywhere near the centre of their mythology"[2]. In order to address the concept of mental North, the first chapter of *Canadian Nordicity* (1979) was dedicated to matters of perception[3]. Previously, the famous Group of Seven had introduced some concepts of the North in Canadian painting.

Other characteristics of my conception of the Arctic and Subarctic zones come directly from my studies in geography. Six years in Western Europe had prepared me for two other aspects of nordology: one concerns the whole dimension of geography which considers facts in both physical *and* human fields; according to that scope you may have a better understanding of the range of criteria in my northern index. So, I am interested in a broad spectrum of sciences; that rash horizon pushed me to publish on periglacial phenomena at one end of the academic spectrum and on population problems at the other. Such a range may seem stupid among students who prepare themselves to spend all their life in only one, secure, narrow, field. Nevertheless, the multidisciplinary approach may lead the way to an interdisciplinary understanding of geographic areas. In fact, I have tried to extend my intellectual process even further by training myself to

practice a kind of global and integrated approach to things. I am almost afraid to tell you that I have no speciality. Rather, I have tried to build opinions on broad political matters. Tonight, the question of northern sovereignty will give me an occasion to use such a comprehensive approach.

You could have already discovered in my writings two other characteristics of nordicity. One of them belongs to the linguistic sciences. Again, I have committed myself to make precise definitions of northern phenomena, even to coin new words and concepts. I did it in French and some of the new meanings such as the circumpolar sense of *nordique* are today in Parisian French dictionaries; in some way, through translations, some of these neologisms have penetrated in Canadian English. Not every scientist is making enough effort to express himself in an acceptable way. The last characteristic of my career may be seen in commitments to serve in public or parapublic offices, such as in the Indian Reserve of Restigouche after the clash between the Quebec Government and Micmacs in 1981.

In the second part of my address, I would like to give an idea of the intellectual content of my conception of nordism through study of four words: *North*, *nordique*, *nordicity* and *nordology*, all of them applied to Canadian situations. But, to respond to the kind invitation of Peter Adams, let me do this in French.

II — Concepts de base du nordisme[4]

Considérons d'abord le mot *nord*, d'après ce que j'en ai écrit[5]. Le contenu du terme tient beaucoup à son histoire. Dans une vue planétaire et millénaire des choses, le mot s'est développé le long de deux principaux axes, déphasés et perpendiculaires; l'un nord-sud, entre les mondes méditerranéen et scandinave, durant l'Antiquité et le Moyen Âge; cela explique que les deux principaux groupes linguistiques du monde qui remuent le lexème *nord* sont des langues romanes et germaniques; la partie froide de ce premier axe était au niveau d'une nordicité de *Pré Nord* seulement. A partir de la Renaissance, une seconde voie va s'ouvrir, celle d'une direction «est-ouest quart au nord», s'étirant à la fois de l'Europe vers l'Asie et de l'Europe vers l'Amérique; c'est ainsi qu'un *Norvik* norvégien a atteint la Sibérie arctique de l'Est et qu'un *Northwest* britannique a débarqué au Mackenzie canadien; également, ce nouvel axe pénètre plus avant dans le Nord et fait reconnaître les zones emboîtées de *Moyen Nord*, *Grand Nord* et d'*Extrême Nord*; la matière étant plus nordique que celle de la première phase, le vocabulaire l'est devenu aussi. Le nord est donc un vieux concept qui accueille des mots nouveaux dans sa propre famille lexicale.

Nordique montre l'apport du Canada dans les langages internationaux. En français de France, le mot est d'abord arrivé très en retard par rapport aux formes linguistiques correspondantes en islandais (au temps des Vikings) et en anglais (XIIe siècle); de plus, *nordique* a longtemps signifié, dans la métropole: «uniquement scandinave»[6]. Au Québec, le qualificatif a d'abord désigné une direction ou une position appliquée à l'Amérique; le changement s'est fait connaître sous trois plans. D'abord au niveau spatial, *nordique* a été circumpolarisé afin de s'appliquer autant à la Scandinavie, à l'Amérique du Nord qu'à l'ensemble du monde froid de l'hémisphère boréal; le sens à donc été étendu au tout et à d'autres régions froides; un tel déblocage a grandement facilité, au Canada, la désignation de multiples choses (établissements, institutions, groupes, lieux, personnes). En deuxième lieu, *nordique* est devenu spécialisé au plan de son contenu sémantique; tout en ne perdant pas son sens directionnel associé aux points cardinaux, il en est venu à désigner une région comportant d'office une certaine charge de nordicité; en fonction de cette acception scientifique, on peut maintenant évaluer combien nordiques sont les pays scandinaves eux-mêmes, eux qui, hier encore, étaient les seuls à avoir droit à ce titre; on découvre alors que des espaces comme le Canada qui n'avaient pas accès à *nordique* ont davantage de nordicité que ceux qui n'étaient pas privés du terme; ce dernier a comme pris une signification plus logique à l'échelle de la géographie mondiale. Enfin, *nordique* s'est également étendu au plan de la désignation d'individus; au sens originel d'habitants de la Scandinavie, se sont ajoutés des nouvelles désignations, une se rapporte à un *nordiste* de résidence dans toute la zone proprement froide du globe, une autre désigne les membres de clubs de hockey tant au Canada qu'aux États-Unis.

Le mot *nordicité*, créé en 1965, est entré dans *Le Grand Robert*, vingt ans après. Le concept rejoint à la fois toutes les réalités circumpolaires réunies et individuellement chacune d'elles. Nordicité s'applique donc à

a- des espaces, organisés ou non, comme le Nord québécois, la Mer de Norvège, le Moyen Nord, l'Alaska, la République de Yakoutie. . . ;

b- à des groupes vivants, humains ou no, tels les «Petits Peuples» de la Sibérie, les Sudistes qui «font du nord», les Nordistes de résidence; on a parlé de la nordicité des balanes (crustacés);

c- à des organismes publics, para-publics et privés comme les administrations nordiques, le Ministère fédéral du Nord, Nunavut, l'Association universitaire canadienne d'études nordiques, le projet d'une université du Nord;

d- à des mentalités; combien ajustées sont les théories de chacun à l'endroit du Nord? la littérature nordique se situe à quel niveau de nordicité? combien de Nord dans le nord du «Groupe des Sept» (peinture)?;

e- à des décisions et des activités developpementales; les grandes centrales hydro-électriques de chaque versant de la mer d'Hudson sont-elles du Nord ou simplement situées dans le nord? Si à peu près toutes les nordicités sont innées chez les Autochtones, il n'en est pas ainsi chez les non-Autochtones où l'écart peut être grand entre une nordicité normative et les nordicités d'usage. Au plan épistémologique, le développement de la notion de *nordicité* a suivi deux préoccupations majeures. Celle de l'analyse géographique qui permet de proposer des limites méridionales aux régions septentrionales, des zonations à l'intérieur de ces immenses étendues (distinction *Moyen Nord Grand Nord*), des bases quantitatives à l'appréciation de son niveau nordique[7]. Cette façon globaliste de voir rompt avec la pratique un peu élémentaire de ne considérer qu'un seul élément à la fois dans les fixations des limites sud du Nord, par exemple, l'isotherme de 10°C., le Cercle arctique, une seule saison, les variations du pack. Les frontières suggérées par le nouvel indice traversent sept provinces, ce qui représente bien mieux la réalité que la latitude du 60° utilisée par les gouvernements, plus soucieux, ici, des relations fédérales/provinciales que de celles entre le Canada de base et le Canada septentrional. Le second objectif concerne avant tout l'aspect mental

Dessin : Isabelle Diaz, Laboratoire de cartographie, Département de géographie, université Laval — *I.-E. Hamelin*

qui fait référence à une nordicité psychologique, perceptive à différents degrés. Dans sa venue, la nordicité mentale est instinctive, empirique, déductive ou simplement imitative. En principe, toutes les nordicités improvisées posent des problèmes d'inadéquation au Nord par rapport à une nordicité idéale, normative, rationnelle ou scientifique; traînent donc des inadaptations, une insuffisance de nordicité — voir même de l'a-nordicité — dans de nombreuses aventures et attitudes se produisant dans le Nord. De telles déviances se sont exercées notamment à l'endroit des Autochtones, de la nature et des gestions. En pratique, il faudrait se méfier de sa nordicité héréditaire, celle que l'on a recueillie de bonne foi dans un Sud du Canada alors insuffisamment informé sur le Nord. Au contraire, il faut réfléchir à sa propre nordication; celle-ci ne peut atteindre un niveau suffisant sans effort. Pour vous, chercheurs, une nordicité satisfaisante constitue un facteur de la qualité des recherches en favorisant le dialogue entre tous les types de nordistes.

The last concept I would like to consider briefly is the one called *nordologie* in French[8] (that could become *nordology* in English?). Fifteen years ago, I also coined that word and gave it the following definition: "study of latitudinal cold areas". In accordance with what I have already said, nordology falls into two levels: one corresponds with specialization in any northern field, usually one for each field. The great majority of northern researchers belong to this first category. Such a situation, which this conference is designed to overcome, reflects the structure of universities; so, we have, above all, a series of individual specialists: geologist, biologist, ethnologist . . . Most of the time, the northern focus as such lags behind or hardly appears. It is not always manifest that the scientific work is "of, in, for, by, with and because of the Canadian North" (Peter Larkin, 1978). Then, many scientists do not see the North as a region (where things are integrated); in fact, they bring more southern views inside the North. I have met some very prestigious and competent individuals restraining themselves from learning something outside their specific field. Is that healthy? Is it the logical way of being knowledgeable?

The second focus of nordology concerns just a few researchers. The listing of northern scientists published by ACUNS/AUCEN in 1978 shows that only 4% were interested by "the Arctic in general"[9]. That focus corresponds to a global approach to studying the North. Any geographical area is like a system where all elements are closely related. In my own bias, monothematic or bithematic approaches cannot solve such broad problems as the following: better relations between North and South, the political implications of the multicultural situation inside the Northwest Territories, the level of the northern consciousness of Southerners, the notion of North in the Canadian External policy. The least we could each search for is an open mind towards others' fields. In the past, geologists such as Peter Low, Robert Bell and botanists such as Jacques Rousseau did not limit themselves to their speciality. Among nordologists, how to reconcile both trends: high specialization or micro-nordology and global perspective or macro-nordology? However, improvements have been made. I realize, after Fred Roots (1986), that "the boundaries between traditional scientific disciplines are changing and becoming indistinct in the Arctic regions. . . . The very distinction between physical and biological sciences as an approach to study of nature has all but disappeared from the leading arctic research". But have we not to facilitate a better dialogue between natural science and human fields, with appropriate methodology? May I also suggest that those who want to test, in the North, their specialized knowledge take some courses beforehand or read on broad northern subjects? In some universities, lectures are given on macro-nordology itself; in some others, programs on northern history, northern ethnography, or northern geography might serve as a substitute. The North needs many high ranked scientists; let us hope that each of them will be a scientist plus. As the range of nordology is circumpolar, a kind of global approach, again, must be practised.

La nordologie comprend un aspect proprement théorique; elle devrait être en mesure d'élaborer une série de documents et de réflexions qui pourraient servir d'orientation et de guide dans les décisions concernant la difficile évaluation des droits d'aborigènes.

Conclusion

Je voudrais terminer en traitant de trois aspects qui débordent le fait de toute nordicité; ils concernent l'écologie du vivre. C'est l'être tout entier qui constitue le support, le véhicule et la condition fondamentale de toute profession; le nordisme n'y échappe pas.

Etudiantes et étudiants, engagez-vous dans une autoévaluation permanente. Le fait de se regarder objectivement me semble être l'une des pièces maîtresses, le solage, de tout édifice. Autrement, comment savoir ce que l'on veut aux divers plans du travail, de l'association de type familial et du cadre de vie? Il est recommandé de commencer par une analyse de son égo. Selon Plutarque, aucun savoir n'est plus utile à l'homme que le savoir sur lui-même.

En outre, l'impatience de la jeunesse ne fait disparaître la fonction temps dans aucune affaire; c'est une vie qui est en jeu, non seulement un premier emploi ou des liaisons temporairement douces; l'attente se traduit naturellement par une durée qui, elle, ne peut éviter toute une série d'exercices conséquents. Personne ne peut s'approprier tout le bonheur tout de suite et pour toute la vie. Le mieux être est plutôt composé d'une suite de points d'équilibre à reconsidérer sans cesse, un peu comme on le fait pour les comportements de la bourse ou face à un écran de radar.

Enfin, faites-vous des plans de vie. Où voulez-vous être à la fin d'un premier dix ans de carrière? A envisager aussi, d'abord à un niveau théorique, le pourcentage approximatif de vos activités professionnelles dans l'ensemble de votre vie. Malheureusement, la majorité des chercheurs n'y semblent fournir aucune réponse claire et se laissent plutôt guider par la séquence des événements. À cet égard, trois voies principales peuvent être choisies: un petit groupe privilégie la carrière à tout prix au détriment d'autres aspects majeurs comme la santé, la famille et le repos; cela conduit au surdéveloppement d'une partie de l'être; ces héros ne sont qu'à plein temps, et dans leur seul sujet, mais ils peuvent recevoir un Nobel! Une autre catégorie de chercheurs rassemble les individus qui, volontairement, tiennent à assurer un équilibre sans cesse à réajuster entre les principaux éléments de leur vie professionnelle, sociale et personnelle; ils ne sont à plein temps nulle part. La troisième catégorie, sans

engagement précis, se laissent ballottés entre les deux pôles précédents. De toute façon, les plans et la profession (nordique) ne devraient pas imposer une démarche rigide et fixiste. Antérieurement, on cherchait à poursuivre la même carrière au même endroit et pendant une vie entière. Maintenant, ces traits d'unité carriériste sont contrecarrés par le style et le rythme du modernisme. On vous a certes déjà conseillé de développer une disponibilité d'esprit et une versatilité des moyens afin d'envisager la mobilité comme trait de votre emploi, plutôt de la série de vos emplois. Par rapport au passé, la vie qui vient en sera probablement une de transition plus grande encore, d'équilibres mobiles entre une histoire accélérée et des avenirs passablement insaisissables. Qui réussira à façonner, puis à entretenir l'harmonie et la synthèse des multiples courants sera celui ou celle qui vivra le plus intensément. La plupart des vies réussies connaissent un grand nombre de renaissances.

Remerciements à M. Peter Adams de l'ACUNS/AUCEN d'avoir bien voulu revoir la forme de la partie anglaise de ce texte.

Footnotes

1 The Arctic in Fact and Fable. New York, 1945, p. 5.

2 In Brian Bird, The Natural Landscapes of Canada. Toronto, Wiley, 1972, p. 1.

3 My personal involvement in mental nordicity starts at the end of the 1950-1960 decade through teaching. See also Direction Nord. Presentation, Royal Society of Canada, Trois-Rivières, Bien public, 17, 1963, pp. 18-26. Image mentale. . .l'exemple du Nord in International Geography, Toronto, 1972. Abstract pp. 1048-1050 and in Didactique-Géographie, I, 3, 1972, pp. 3-9.

4 nordisme 2- Ensemble des attitudes mentales ou des activités exprimant un engagement en faveur du Nord. Le Robert, Paris, tome VI, 1985, p. 803.

5 Le mot Nord et son langage. Québec, Office de la langue française, 1978, 2 tomes.

6 Larousse, Le Lexis, 1986.

7 La première ébauche de cette conception a été publiée dans North/Nord, Ottawa, MAIN, XI, 4, 1964, pp. 16-19 (et carte). Traduite en anglais en 1971 (Wonders) et 1973 (Jackson). Une version plus élaborée apparait dans Nordicité canadienne 1975; en anglais, 1979 (Barr). Le sujet a été repris par un certain nombre d'auteurs et appliqué même à l'Antarctique. Voir aussi The Canadian Encyclopedia, Edmonton, 1985.

Moyen Nord devient Middle North et Grand Nord, Far North.

8 Nous préférons ce terme à nordographie de C. Morissonneau. L.-E. Hamelin. Le Nord et son langage, Québec, Office de la langue française, fasc. II, 1978, p. 229.

9 The percentage is 17% in the second edition of the List, 1983.

Bibliographie

ACUNS/AUCEN, List of Northern Specialists at Canadian Universities. Ottawa, 1978, 189 p.; 2e éd., 1983, 206 p. Bilingue.

Canada, Science and the North. A Seminar on Guidelines. . .Northern Canada, 1972. Ottawa, INA, 1973, 287 p. Ed. by K. Greenaway.

Conseil des Universités, Les défis de la recherche nordique au Québec. Québec, 1981, 119 p. +

Désy, Pierrette, The North: Utilitarian Conscience of the South. Ottawa, AUCEN/ACUNS, Occ. Publ. 9, 1984, pp. 25-39.

Dubé, Y., A Northern Approach to Northern Science. Address, Conference, Edmonton, 1986, 15 p.

Hamelin, L.-E. Nordicité canadienne. Montréal, HMH, 1980 (2e éd.), 438 p. Traduite en anglais par W. Barr, Canadian Nordicity. Montréal, Harvest House, 1979, 373 p.

Larkin, P., Science and the North: An Essay on Aspirations. Northern Transitions, éd. par Keith et Wright, Ottawa, CARC, 1978, pp. 119-127.

Roots, E.F., International and Regional Cooperation in Arctic Science: A Changing Situation. The Musk-Ox, Saskatoon, 34, 1986, pp. 9-27.

Rousseau, J., Areas of Northern Research Deserving Greater Attention. Proceedings of the First National Northern Research Conference, Saskatoon, 1968, pp. 89-94.

Symons, T.H.B., Some Thoughts on the Current State of Teaching and Research about Northern Canada. Ottawa, AUCEN/ACUNS, 1980, 13 p.

Tremblay, M.A., La recherche universitaire nordique dans les sciences humaines. . . Recherches amérindiennes au Québec, XIV, 3, 1984, pp. 90-95.

University of Canada North. Documents, réunion, Inuvik, 1971.

Washburn, A.L. et G. Weller, Arctic Research in the National Interest. Annals, Ass. for the Advancement of Sc., 223, 1986, pp. 633-639.

A. PHYSICAL SCIENCES
SCIENCES PHYSIQUES

CRETACEOUS VOLCANISM ASSOCIATED WITH DEVELOPMENT OF THE SVERDRUP BASIN, ELLESMERE ISLAND, ARCTIC ARCHIPELAGO- PRELIMINARY RESULTS FROM RECENT MAPPING

Jennifer L. Bates

Department of Geology, Dalhousie University, Halifax, Nova Scotia B3H 3J5

Level: Master's

Abstract

During the Cretaceous, significant volcanic activity was associated with continental rifting, crustal extension and development of the Sverdrup Basin. The associated volcanic units, which can be observed today on northwestern Ellesmere Island, are the topic of a study aimed at defining their role in the formation of the basin. The thermal effect of lava emplacement on basin development, and hence on maturation of hydrocarbons associated with the sedimentary units, is of particular interest to oil and gas exploration. Sections of volcanic rocks were measured and sampled at two field sites in 1986, one immediately south of Audhild Bay and the second near Phillips Inlet. Cliff exposures in the Audhild Bay area contain over 200 m of interbedded aphyric and plagioclase-pyroxene porphyritic volcanic flows which are rarely interrupted by porphyritic glass, ignimbrite, and felsic and pyroclastic volcanics. The felsic volcanics are crosscut by basic dykes. The thickness of individual flows varies from 2-3 metres to 30 metres. The thicker flows often exhibit spectacular columnar jointing. Generally the flows dip gently (i.e. 5°-15°) to the west and their regional continuity may be defined by comparison with volcanic units in the Phillips Inlet area (site 2) and (or) the Cretaceous rocks of the Strand Fiord Formation. All volcanic units in the study area are fresh which is most opportune for geochemical and isotopic studies. These studies will aid in the definition of the paleoenvironment, and the determination of magma source, mode of ascent and emplacement. Time(s) of eruptive activity may be defined by age dating of appropriate flows.

Key words: Cretaceous, Ellesmere Island, Sverdrup Basin, volcanic, continental rifting, petrology, geochemistry, paleoenvironment.

Résumé

Au cours du Crétacé, la formation du bassin de Sverdrup s'accompagna d'une forte activité volcanique contemporaine de l'extension de la lithosphère et de la dérive continentale. Les coulées issues de cette activité, et qu'on observe de nos jours dans le Nord-Ouest de l'île d'Ellesmere, constituent la matière d'une étude visant à éclaircir leur rôle dans la formation de ce bassin. Les effets thermiques de l'épanchement des laves sur la formation du bassin, et en conséquence sur la bitumination des hydrocarbures présents dans les couches sédimentaires, est d'un intérêt particulier pour les chercheurs de formations pétrolifères ou gazifères. Au cours de l'été 1986, ces scientifiques ont établi deux camps d'exploration, l'un immédiatement au sud de la baie Audhild, et l'autre dans les alentours du bras de mer Phillips, afin de mesurer l'épaisseur des coulées volcaniques et d'extraire des carottes pour analyse. Les premières observations réalisées dans la baie Audhild ont mis en évidence une épaisseur de 250 à 300 m de coulées de basalte porphyrique à pyroxène et plagioclases, alternant avec des coulées non porphyriques, et souvent à découvert dans les escarpements. Ces coulées sont rarement interrompues par des coulées d'obsidienne, d'ignimbrite et de felsite. L'épaisseur des coulées individuelles varie de 2 ou 3 m jusqu'à 30 m. Les plus épaisses montrent souvent une configuration spectaculaire en orgue. En général, la pente des coulées est assez douce (de 5 à 15°) vers l'ouest. Sur le plan régional, on peut établir la continuité de ces coulées avec celles de la région du bras de mer Phillips. Elles sont toutes inaltérées, ce qui est précieux pour les analyses géochimiques et isotopiques et aide à préciser le paléoenvironnement des laves. On peut préciser les époques d'activité volcanique par la datation isotopique de coulées choisies.

Mots-clés: Crétacé, île d'Ellesmere, bassin de Sverdrup, matières volcaniques, dérive continentale, basalte.

Introduction

The Cretaceous volcanic rocks which outcrop along the northwestern coast of Ellesmere Island in the Canadian Arctic are the subject of M.Sc. thesis research undertaken by the author. Field investigations were initiated in July 1986 with the establishment of 2-person field parties at Audhild Bay and Phillips Inlet. This paper summarizes observations made at the former site. Figure 1 indicates the location of the study area.

No other detailed study of these volcanic rocks exists and therefore little is known of their age, composition, stratigraphy and petrogenesis. However, Cretaceous volcanics are believed to have erupted in conjunction with rifting, extension and development of the Sverdrup Basin (Balkwill, 1978). In 1985, K. Osadetz of the Institute of Sedimentary and Petroleum Geology in Calgary, Alberta discovered that these volcanic rocks, once mapped as Carboniferous (Thorsteinsson and Trettin, 1970), were possibly Cretaceous (G.K. Muecke, personal communication, 1985). Therefore, a petrographic, geochemical and stratigraphic study of these rocks is expected to lead to an interpretation of their origin, mode of ascent and emplacement, and their paleoenvironment or role in the development of the Sverdrup Basin.

This paper is based on initial field observations. The results are preliminary and subject to change as detailed petrological and geochemical study progresses.

Regional Geology

Simply stated, the rocks of the Canadian Arctic Archipelago form a system of geological entities that become generally younger to the north from the cratonic interior to the continental margin (Balkwill, 1978) (Fig. 1). As one of these entities, the Sverdrup Basin is a northeast-trending elongate structural depression approximately 1300 km long and as much as 400 km wide in the north-central region of the Arctic Archipelago. The basin overlies deformed rocks of the Franklinian Basin. In axial regions of the Sverdrup basin, the succession is mainly concordant, although unconformities are present along the margins.

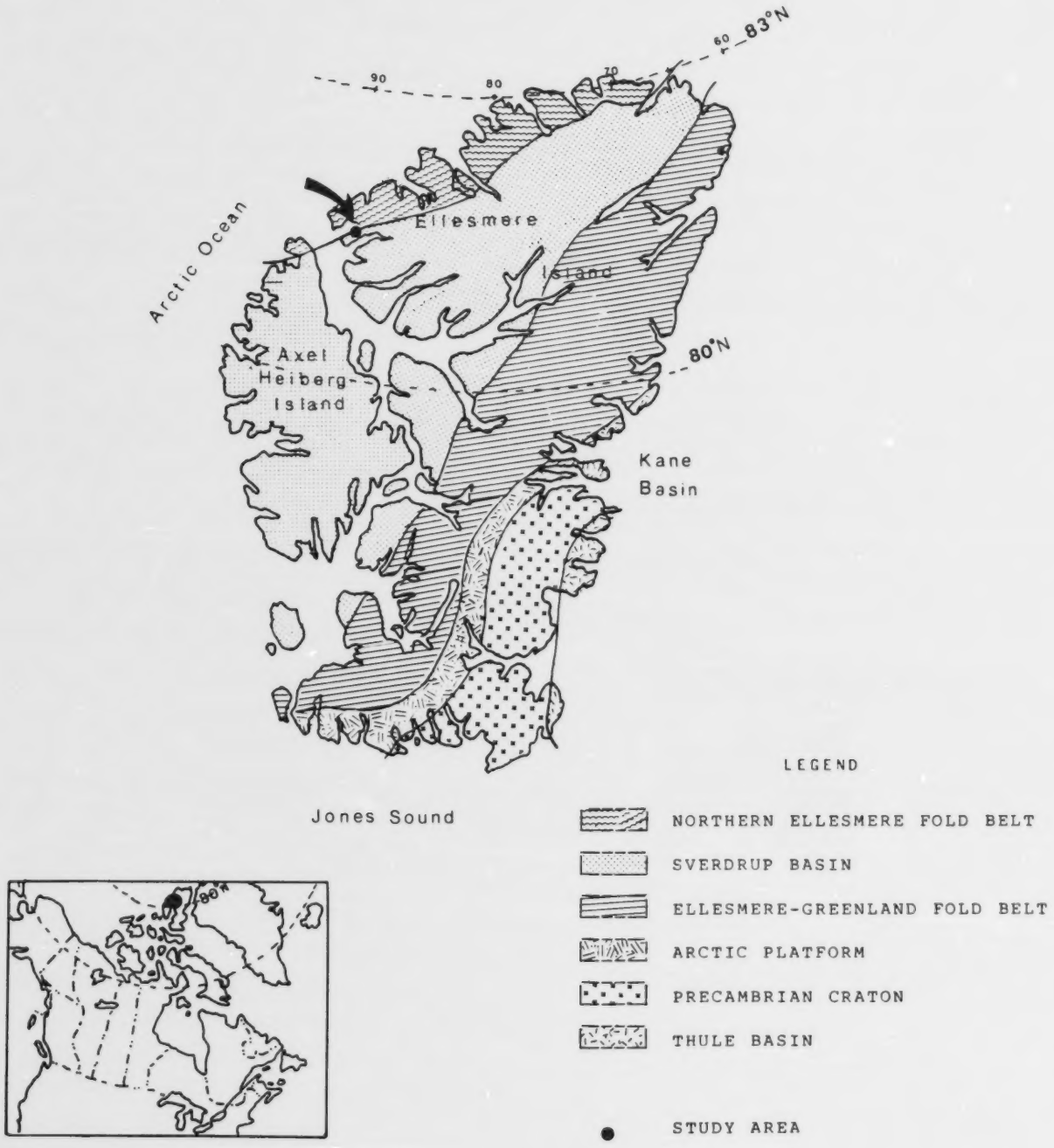


Figure 1 Location of the Audhild Bay study area of northwestern Ellesmere Island, Arctic Archipelago. The map shows the main stratigraphic and structural units of Ellesmere Island and Axel Heiberg Island (after Dawes and Kerr, 1982).

The Sverdrup Basin contains up to 13 000 m of Lower Carboniferous to Upper Tertiary marine and nonmarine terrigenous clastic, carbonate and evaporite strata, local abundant dykes and sills, and basalt flows (Balkwill, ibid). Basalt flows as well as mafic dykes and sills are associated with Mesozoic and older sedimentary rocks of the Sverdrup Basin. The episodes of mafic extrusion are believed to have coincided approximately with times of accelerated basin subsidence (Balkwill, ibid).

The volcanic units examined in this study represent part of this volcanic activity and are therefore significant to the processes coincident with basin development.

Field relations

Measured and sampled sections and outcrops in the Audhild Bay area are noted in Figure 2 and Table 1. Eight sections were examined and the resultant stratigraphy is shown in Figures 3 and 4. Representative photomicrographs of the predominant units appear as Figures 5a to 5d. At this time, no attempt is made to correlate the volcanic units.

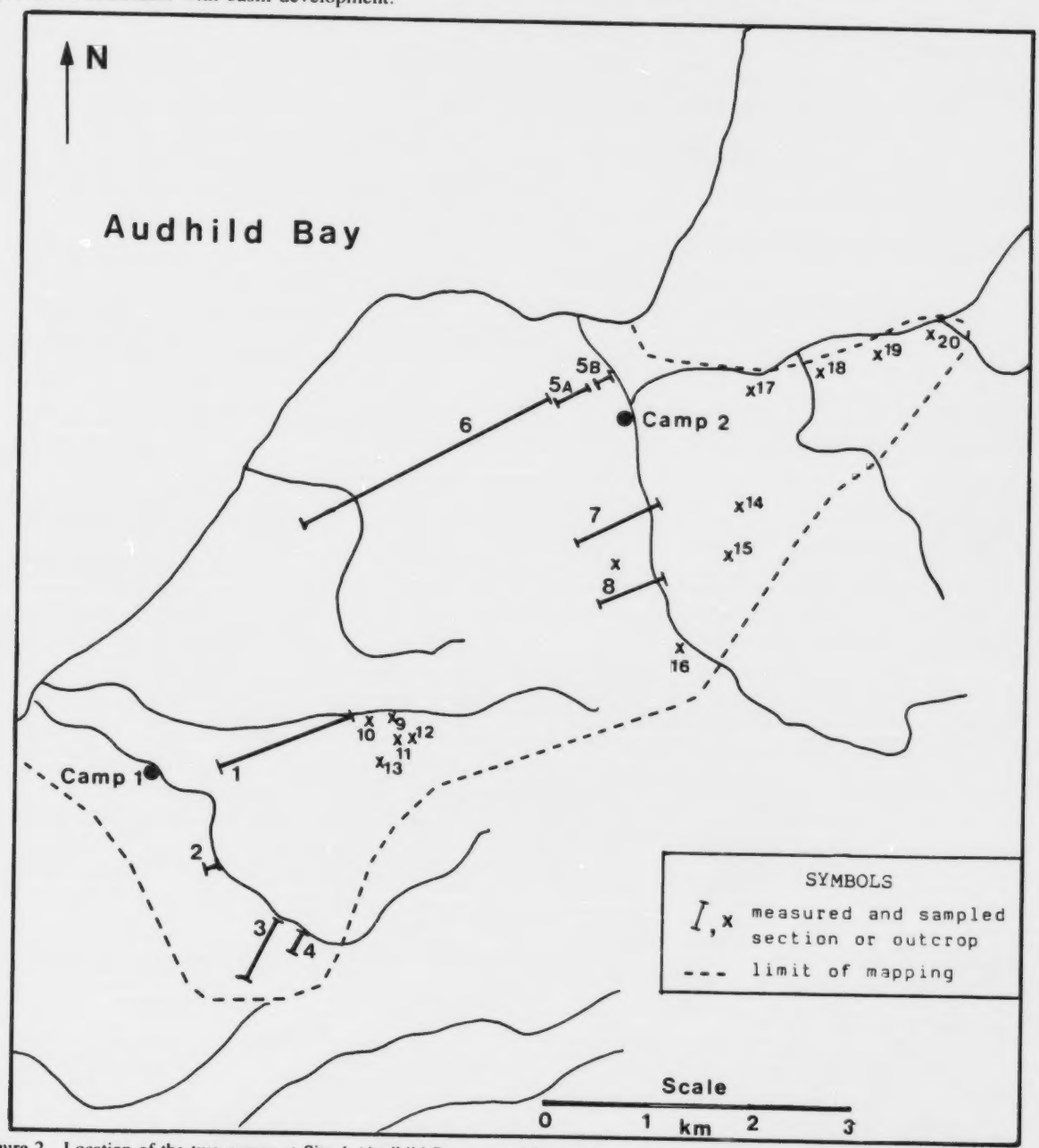


Figure 2 Location of the two camps at Site 1 (Audhild Bay area). Measured and sampled sections and outcrops are noted. Numbers correspond to sections shown in Figures 3 and 4.

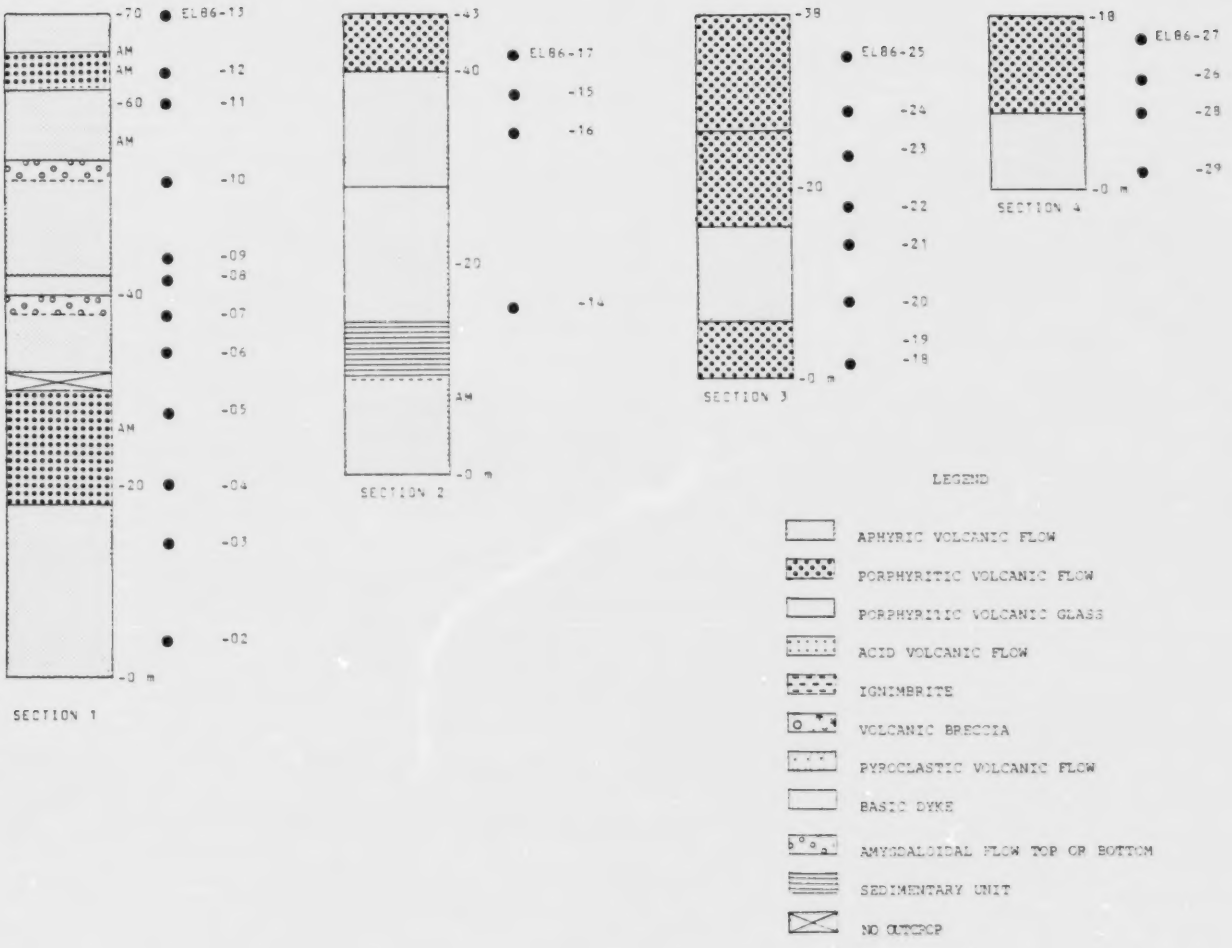


Figure 3 Stratigraphic columns of sections 1,2,3 and 4 of the study area. Sample locations and numbers appear to the right of each column. Amygdules are noted as either present throughout the unit (denoted as AM to the right of the column) or as a discrete portion of the unit (denoted by a dashed line).

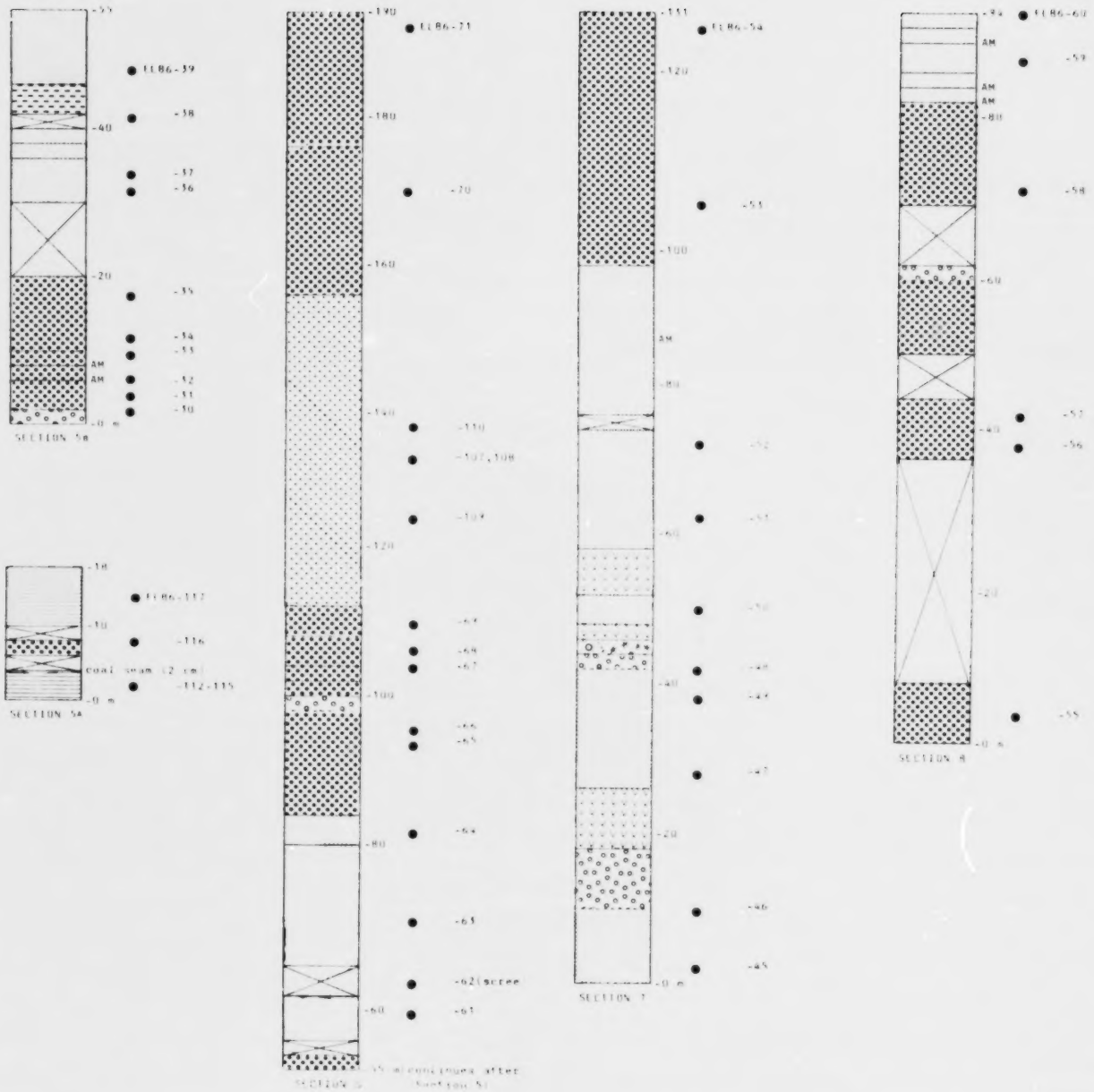
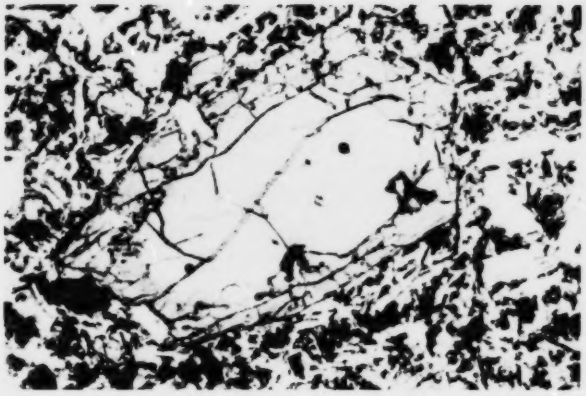
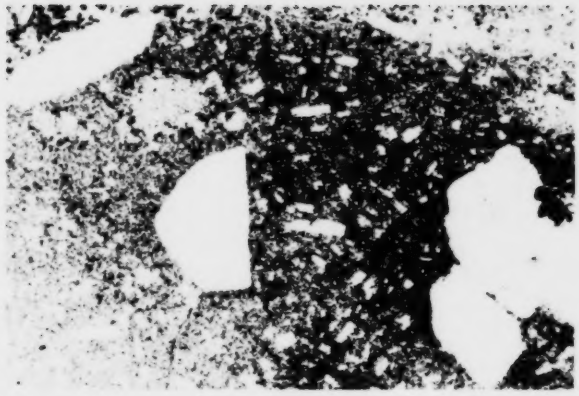
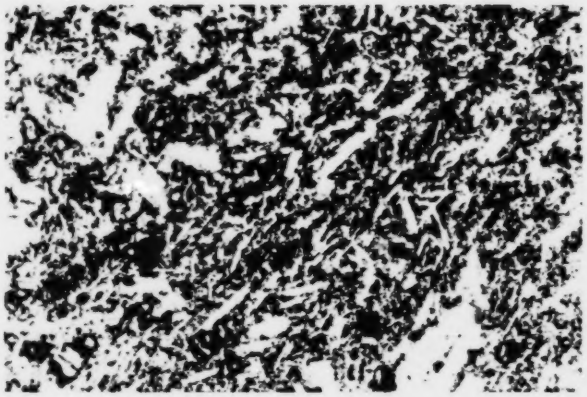


Figure 4 Stratigraphic columns of sections 5,6,7 and 8 of the study area. Explanations and legend are as shown in Figure 3.







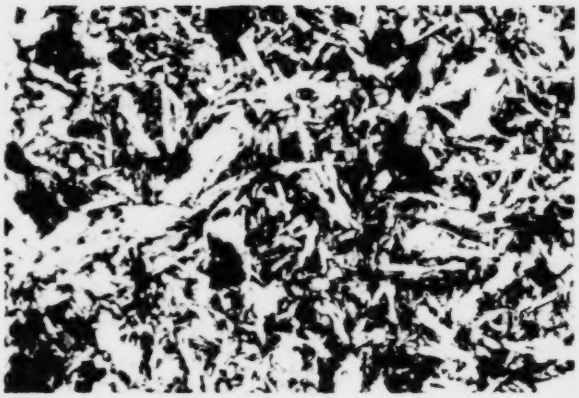


Figure 5a Photomicrograph of the porphyritic volcanic unit showing a pyroxene phenocryst in a fine grained groundmass of plagioclase, pyroxene and accessory minerals. Field of view 7 mm.

Figure 5b Photomicrograph of the aphyric volcanic flow unit. Intergranular relationship of pyroxene, plagioclase and opaques. Field of view 7 mm.

Figure 5c Photomicrograph of the porphyritic glass (pitchstone?). Plagioclase phenocrysts in a groundmass of plagioclase microphenocrysts in a cryptocrystalline matrix. Field of view 7 mm.

Figure 5d Photomicrograph of the basic dyke rock. Intergrown plagioclase, pyroxene and opaques. Field of view 7 mm.

TABLE 1
Rock types corresponding to outcrops shown in Figure 2.

OUTCROP NUMBER	ROCK TYPE	COMMENTS
9	porphyritic glass	banded on mm scale; pitchstone?
10	"	crude banding; vugs
11	aphyric volcanic flow	olivine?
12	"	same as unit 1 of Section 1
13	porphyritic volcanic flow	olivine?
14	aphyric/porphyritic volcanic flows	70–50 m; columnar jointing (30 cm)
15	"	25 m; 2–3 flows
16	porphyritic volcanic flow	small gossan to the south
17	aphyric volcanic flow	20–25 m; higher % plagioclase
18	"	15 m; near fault
19	"	3–4 m; dip 10°E
20	"	10–15 m

Within the field area, the following distinct geological entities were identified:

1. aphyric volcanic flows,
2. porphyritic (plagioclase + pyroxene) volcanic flows,
3. prophyritic (plagioclase) volcanic glass,
4. acid volcanic flows,
5. ignimbrite,
6. volcanic breccia,
7. pyroclastic volcanic flows,
8. basic dykes
9. sedimentary units (sandstone, conglomerate, siltstone and coal).

The aphyric and porphyritic volcanic flows are commonly amygdaloidal. Where the amygdules define a top or bottom of a flow, the unit is noted on the stratigraphic sections (Fig. 3 and 4) with a dashed line. The designated units are based on field observations. Detailed mineralogical and petrological analyses remain to be performed.

At present the stratigraphic section of the thesis area is not complete. However, it is worthwhile summarizing the more representative sections shown on Figure 2.

Section 1 (Fig. 3) depicts a 70 m sequence of interbedded aphyric and porphyritic units overlying a unit of porphyritic glass (pitchstone?). Amygdules are common, as is usual with the aphyric and porphyritic flows, and they define the limits of some of the flows. As many as eight flows are present in this section.

Section 2 (Fig. 3) has 43 m of interbedded aphyric and porphyritic units interrupted by one 5 m sedimentary unit (siltstone? sandstone?). The section consists of four units of which three are volcanic flows.

Sections 3 and 4 (Figs. 3 and 4) are interbedded aphyric and porphyritic units divided into four and two flows of 38 m and 18 m thickness, respectively.

Section 5 has two segments, A and B (Fig. 4) separated by an area of cover. Section 5A is an 18 m composite of interbedded sandstone, conglomerate and mudstone interrupted by a single volcanic unit. A thin (2 cm) coal seam tops the stratigraphically lowest unit of sedimentary rocks.

Section 5B has seven flows of interbedded aphyric and porphyritic volcanic units with a 4 m unit of ignimbrite located at 43 m. The total thickness is 55 m.

Section 6 is probably the most varied of the sections. It measures 135 m but with Sections 5A and 5B, which lie immediately below in the section, the total is 190 m. Aphyric and porphyritic volcanic units are present as interbedded flows with a predominance of the latter. However, the lower part of the section is dominated by two units of porphyritic (plagioclase-bearing) volcanic glass (pitchstone?), and at the midpoint of the section acid volcanics are intruded by two basic dykes of 2.5 m width. In total, 12 distinct flow units are recognized.

Sections 7 and 8 are exposed in the steep walls of a valley. While this may be the ideal exposure, the outcrop is not always easily accessible. In Section 7 interbedded aphyric and porphyritic flows and pyroclastic volcanic flows are interrupted once by a 2 m segment of volcanic breccia. Composed of 12 volcanic units, the section measures 131 m. Section 8 is a 94 m composite of nine interbedded aphyric and porphyritic flows separated by areas of cover.

The flows are not necessarily continuous on the scale of the study area, and further study of the field relations (in conjunction with other aspects of the study) at Audhild Bay and Phillips Inlet will aid in the determination of the areal extent of the volcanic units. The pristine nature of the rocks allows for a range of geochemical analyses, including major and trace element, rare earth element and isotopic studies. A few fresh, fine grained samples will possibly be age dated.

Discussion

Field studies have defined a stratigraphic package of igneous and minor sedimentary rocks 100s of metres thick. The presence of coal in the sedimentary units, the sedimentary rock types and the features of the volcanic units suggest the paleoenvironment was the continental margin associated with the development of the Sverdrup Basin.

The Audhild Bay area volcanics represent a bimodal suite of basic flows and dykes and felsic flows. The continuity of this volcanic suite is not established at this time. However, further interpretation of the field relations in addition to mineralogical/petrological study are expected to aid in the definition of the areal extent of these units. As well, comparison with the volcanic sequence at Phillips Inlet is expected to constitute a segment of the intended work and in the future a statement on the relationship (i.e. presence or absence of correlation) between the two areas may be possible.

The author hopes that satisfactory samples will allow for REE analyses, isotopic studies and age dating. These data will supplement the mineralogical/petrological/geochemial data when attempting to answer the following questions:

1. what was the petrogenesis of the volcanic units?
2. what was the magma source?
3. what was the mode of ascent?
4. what was the mode of emplacement?
5. what was the paleoenvironment of the volcanic rocks?
6. what was the role of this volcanic activity in the formation of the Sverdrup Basin?
7. how do these rocks compare with and relate to other volcanic rocks of the Sverdrup Basin (i.e. Strand Fiord Formation)?
8. what was the influence of volcanic activity on the potential hydrocarbon reserves of the Sverdrup Basin?

Acknowledgments

Sincere appreciation is extended to Drs. G.K. Muecke and D.B. Clarke for planting the 'Arctic bug' in the author's ear. Kirk Osadetz of the Institute of Sedimentary and and Petroleum Geology, who initially recognized the Cretaceous volcanic flows at Audhild Bay, is acknowledged for his generous sharing of field data and samples. The Polar Continental Shelf Project personnel, particularly Barry Hough, and the Geological Survey of Canada were essential to the efficient co-ordination of field operations. Barry Cameron, contributing member of the Arctic Studies Group at Dalhousie University, made the field study 'An Arctic Adventure'. Anne Muecke, Jody Tilsey and Steven Philips — thanks for the game of Trivial Pursuit.

References

Balkwill, H.R. 1978. Evolution of Sverdrup Basin, Arctic Canada. The American Association of Petroleum Geologists Bulletin 62(6):1004–1028.

Dawes, P.R. and Kerr, J.W. 1982. The case against major displacement along Nares Strait. In Dawes, P.R. and Kerr, J.W., eds. Nares Strait and the Drift of Greenland: A Conflict in Plate Tectonics. Meddr Grönland, Geoscience 8:369–386.

Ricketts, B., Osadetz, K.G. and Embry, A.F. 1985. Volcanic style in the Strand Fiord Formation (Upper Cretaceous), Axel Heiberg Island, Canadian Arctic Archipelago. Polar Research 3:107–122.

Thorsteinsson, R. and Trettin, H.P. (compilers). 1970. Geological Survey of Canada Map 1305A, Cape Stallworthy, District of Franklin, scale 1:250 000.

MORPHOLOGIE ET SÉDIMENTOLOGIE DES MORAINES DE DE GEER DE LA RÉGION DE LA RIVIÈRE LA GRANDE, QUÉBEC

Luc Beaudry

Département de Géographie, Université d'Ottawa, Ottawa, Ontario K1N 6N5

Niveau: Maîtrise

Résumé

Le but de cette étude est de présenter les résultats préliminaires d'une analyse morphologique et sédimentologique de 17 moraines de De Geer situées à l'est de la baie de James, dans la région de Radisson. Les moraines sont surtout constituées de sable moyen, n'offrant pas de structures apparentes. De plus, la fraction inférieure à 0,063 mm présente un mode.

Les moraines de De Geer forment des populations pouvant parfois compter une centaine de crêtes successives qui s'étendent sur plusieurs kilomètres. Leur distribution spatiale est limitée à l'ouest par la moraine de Sakami et à l'est, par la limite marine. On les retrouve enfin dans les zones basses au relief peu accentué.

Au point de vue morphologie, les moraines sont parallèles entres elles, d'une hauteur variant entre 1 m et 10 m et espacées de 150 m à 200 m. Elles atteignent en moyenne 250 m de longueur et ont une largeur d'environ 30 m. Les moraines étudiées reposent vraisemblablement sur du till et sont recouvertes partiellement par les argiles de la Mer de Tyrrell.

Mots-clés: Moraines de De Geer, baie James, morphologie, sédimentologie

Abstract

The object of this study is to present preliminary results of a morphological and sedimentological analysis of 17 De Geer moraines located east of James Bay, in the area of Radisson. The moraines are formed of medium sand and do not contain any apparent structures. The fraction under 0,063 mm represents a maximum.

The De Geer moraines are grouped into clusters of up to a hundred or more crests parallel to one another. Their spatial distribution is limited to the west by marine limit. They are also confined to lowlands with little topographic relief.

Morphologically speaking, the moraines are roughly parallel, with a variable height of 1 m to 10 m and with a distance of 150 m to 200 m between them. On average, they reach 250 m in length and have a width of approximately 30 m. The moraines lie most likely on till and are partially covered by Tyrrell Sea clay.

Key words: De Geer moraines, James Bay, morphology, sedimentology

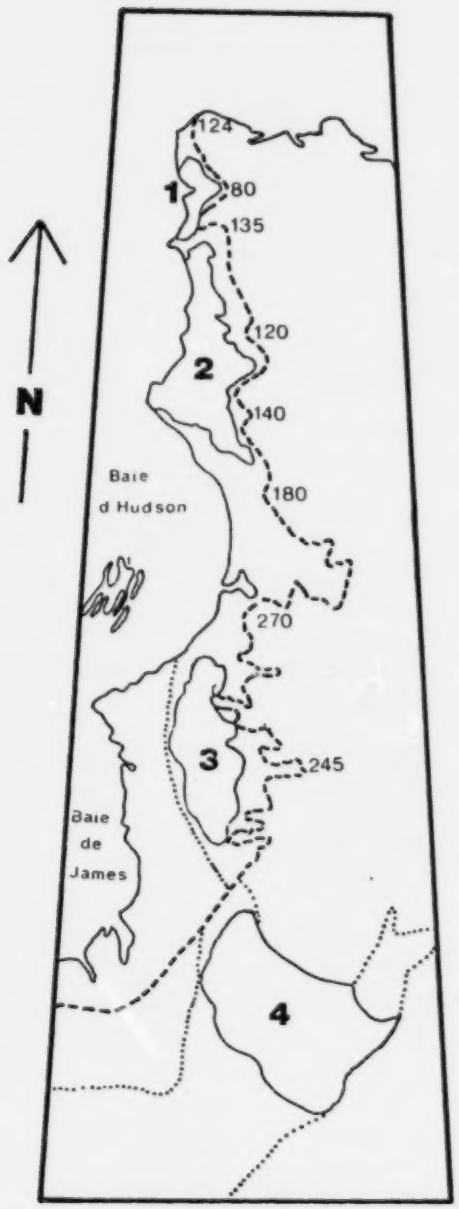
Introduction

Le but de cette étude est de présenter une analyse sédimentologique et morphologique des moraines de De Geer à l'est et au sud-est de la baie d'Hudson. A l'intérieur de cette zone longue de 1 500 km, nous avons sélectionné quatre champs de moraines. Chacun sera l'objet de nos recherches. Il s'agit des champs Opémiska, Chisasibi, Povungnituk et Kovik (figure 1). Les deux premiers ont été visités au cours de l'été 1986 et les autres seront analysés par photo-interprétation. Dans cet article, nous présentons quelques uns de nos résultats, en particulier ceux de la baie de James (champ Fort-George).

Le champ de moraines

La zone de l'étude est située à 50 km au sud du village de Radisson, sur le versant est de la baie de James (figure 2).

L'examen de la littérature traitant des moraines de cette zone démontre qu'elles n'ont pas été étudiées en profondeur par les différents auteurs. En effet, Shaw (1944), Lee



LÉGENDE

1 Champ Kovik

2 Champ Povungnituk

3 Champ Fort-George

4 Champ Opémiska

Limite marine maximale

Limite du lac glaciaire Ojibway

245 **Altitude de la limite marine**

Figure 1 Distribution des champs de moraines de De Geer du Québec, d'après Beaudet et Lauriol (1983).

(manuscrit), Hardy (1976) et Vincent (1977) ont analysé ces moraines, mais ils se sont limités à leur cartographie ainsi qu'à la description de leur morphologie et ne donnent qu'un bref aperçu du matériel qui les composent.

Selon Hardy (1976, p. 15), le substratum de la zone d'étude est essentiellement constitué de «roches métavolcaniques et métasédimentaires, incluant des bandes de roches intrusives», ainsi que de «roches intrusives, massives ou foliées, comprenant des lambeaux de roches métavolcaniques et métasédimentaires».

D'autre part, la topographie de l'ensemble est caractérisé par des altitudes réduites, un relief légèrement ondulé, une dominance des plaines ainsi que par la présence d'épaisses couches de dépôts meubles. Ces derniers ont été mis en place lors de la déglaciation qui aurait eu lieu vers 8 100 BP, date à laquelle la Moraine de Sakami se serait formée (Hardy, 1982). D'après Hillaire-Marcel *et al.*, (1981, p. 212), l'activité du glacier dans cette zone se serait poursuivie pendant environ 500 ans après la mise en place de la Moraine de Sakami. Cependant, les moraines de De Geer étudiées étant directement adjacentes à la Moraine de Sakami, leur âge serait plus rapproché de 8 100 BP.

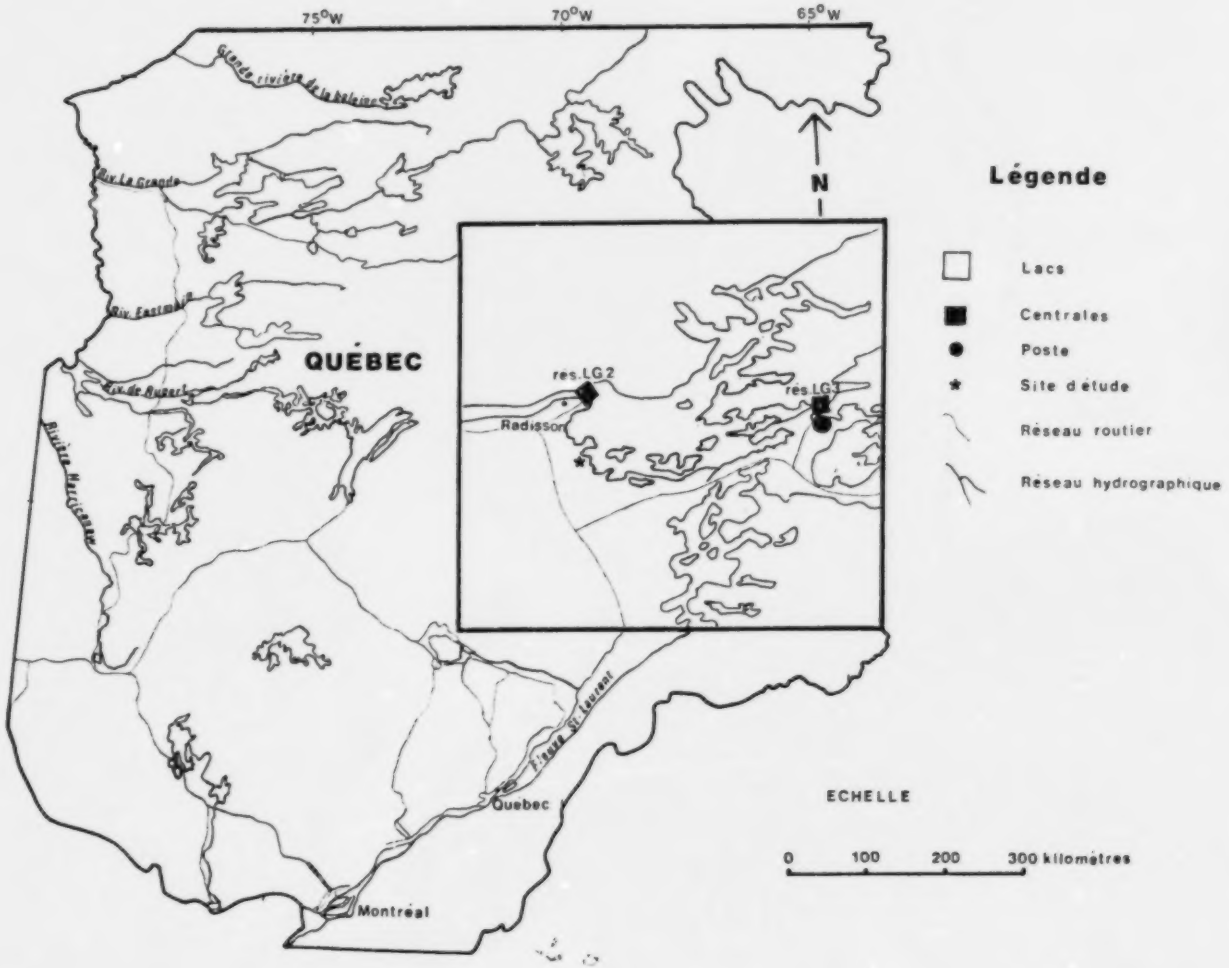
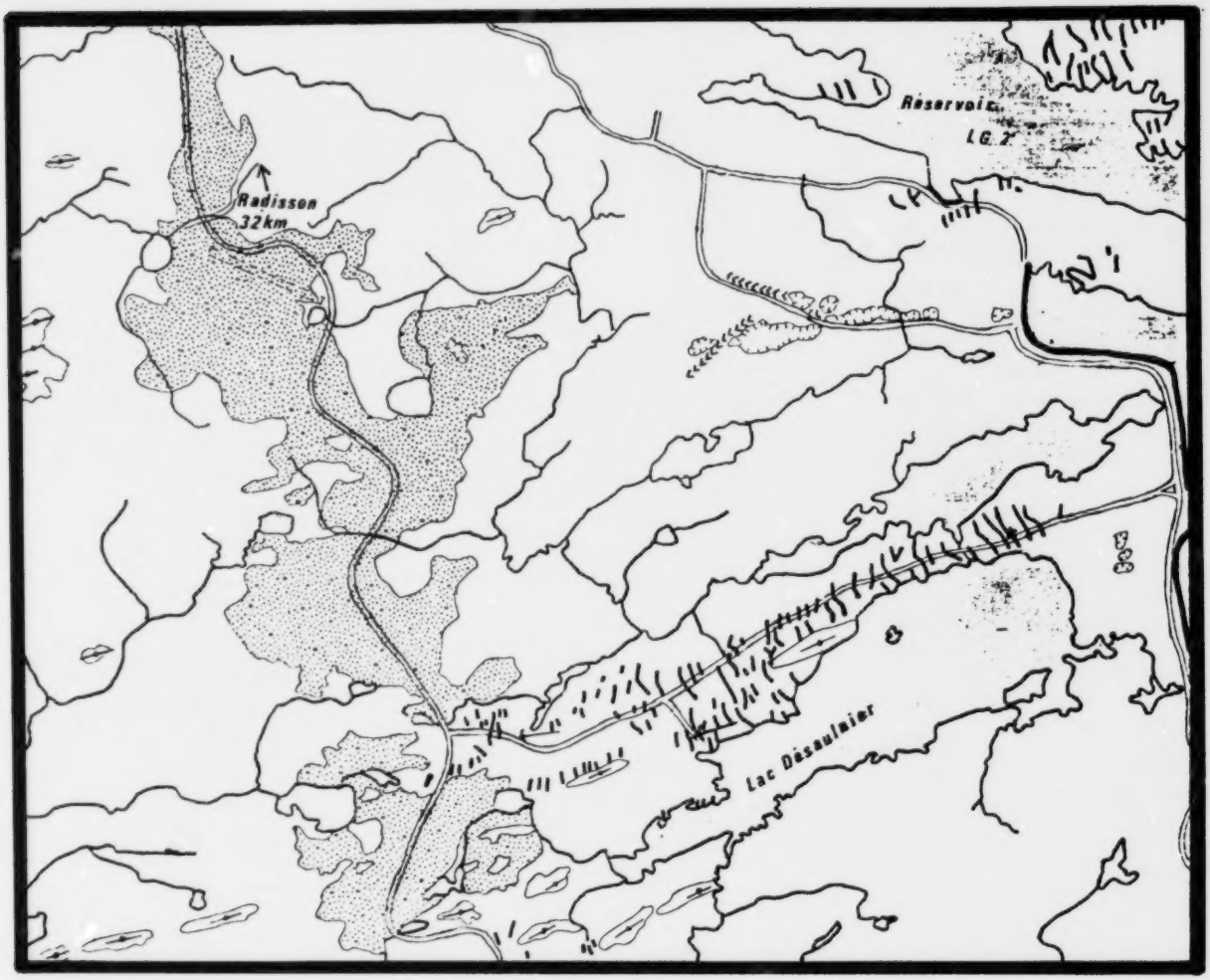


Figure 2 Localisation du champ de moraines de De Geer de Fort George.



Légende

- Moraine de Sakami
- Lacs
- Reseau hydrographique
- Kettles
- Drumlins
- Stries glacière
- Eskers
- Moraines de De Geer
- Digues Duncan
- Réseau routier
- Piste d'atterrissage LG 2
- Moraine LG1

Échelle

2 0 2 4 Kilometres

Figure 3 Géomorphologie de la région étudiée, d'après Vincent (1985a,b).

Morphologie des moraines

Les moraines de De Geer du site à l'étude forment un ensemble de crêtes successives, plus ou moins parallèles les unes aux autres (figure 3) et sont groupées en communautés pouvant atteindre une centaine d'individus. Ces dernières sont distantes d'environ 75 m à 350 m, pour une valeur moyenne de 182 m. Ces résultats se rapprochent des 200 m obtenus par Hillaire-Marcel *et al.* (1981, p. 212) dans la même zone.

La morphologie des crêtes morainiques est assez difficile à déterminer puisque la plupart d'entres elles sont recouvertes, en bonne partie, par les argiles de la mer de Tyrrell, ainsi que par des tourbières. Par contre, il est possible de tirer certaines informations à partir de nos observations et celles des auteurs qui ont étudié cette région.

De manière générale, les auteurs admettent que les moraines ont une pente plus forte du côté distal que du côté proximal. Ceci est vrai sur l'ile de Baffin (Andrews, 1963), en Suède (Hoppe, 1959), en Finlande (Mansikkaniemi, 1973), en Norvège (Sollid et Carlson, 1984) et au Québec. Cependant, dans le cas des moraines que nous avons mesuré, la pente du côté distal est plus forte dans 55% des cas, contre 37% pour la pente proximale, alors que dans 8% des mesures, les pentes étaient égales des deux côtés. Zilliacus (1981, p. 23) a observé lui aussi des pentes égales des deux côtés de la crête morainique dans l'archipel Vasa, à l'ouest de la Finlande. Ces valeurs oscillent entre 1° et 20° du côté distal et proximal, pour la partie émergeant des argiles dans la zone à l'étude.

Selon Lee (manuscrit), les moraines du champ Fort-George ont une hauteur variant entre 0,6 m et 5 m. En effet, nos observations tendent à confirmer les dires de Lee avec la nuance que la limite maximale, dans ce cas-ci, est de l'ordre de 6 m. De plus, elles ont généralement une forme très évasée, puisque les largeurs oscillent, dans cette région, entre 10,6 m et 115,6 m. Enfin, leur longueur se situe entre 29 m et 580 m et leur surface est parsemée de blocs.

Si nous comparons les moraines de De Geer du champ Fort-George avec celles du champ Opémiska, les premières apparaissent nettement plus évasées que les secondes. Cependant, les hauteurs sont à peu près du même ordre dans les deux cas et il en est de même pour la longueur des segments morainiques. De plus, la dissymétrie des moraines du champ Opémiska est plus marquée, c'est-à-dire que la différence entre les pentes du côté distal et du côté proximal est plus prononcée, le premier étant en pente plus forte que le second. Enfin, leur surface est recouverte de blocs dans des proportions semblables, dans les deux champs de moraines de De Geer qui ont été l'objet de nos visites. Par contre, ce recouvrement ne correspond pas à ce qui a été observé ailleurs, dont le champ Povungnituk (Lauriol, communication personnelle), où les blocs sont concentrés surtout du côté distal. Il est possible que cette différence résulte du fait que le lieu d'étude est sous couvert forestier, d'où la difficulté d'observer certains phénomènes.

Relations avec les autres formes du modelé de déglaciation

Les moraines de De Geer du champ Fort-George entrent en contact avec un bon nombre d'autres formes du modelé que nous attribuons au glacier du Nouveau-Québec. En effet, elles sont accompagnées de la moraine de Sakami, d'eskers, de drumlins et de stries glaciaires.

La caractéristique la plus importante à retenir dans ces relations entre formes est que les moraines de la zone étudiée sont absentes à l'ouest de la moraine de Sakami et sont limitées à l'est, par la limit marine. Ceci implique qu'elles ont été mises en place au contact du glacier du Nouveau-Québec et de la Mer de Tyrrell puisque la moraine de Sakami marque la vidange du lac glaciaire Ojibway et le début de la phase marine (Vincent et Hardy, 1979).

Nous notons également que les moraines de De Geer sont à peu près perpendiculaires aux eskers et à l'axe longitudinal des drumlins (Vincent, 1985 a et b). Enfin, les stries ont une orientation moyenne de 245° alors que la direction de l'axe des crêtes morainiques varie entre 138° et 198°, pour une valeur moyenne de 158°, soit une différence de 87° par rapport à l'orientation des stries. Les moraines de De Geer sont donc perpendiculaires au sens de l'écoulement de la glace.

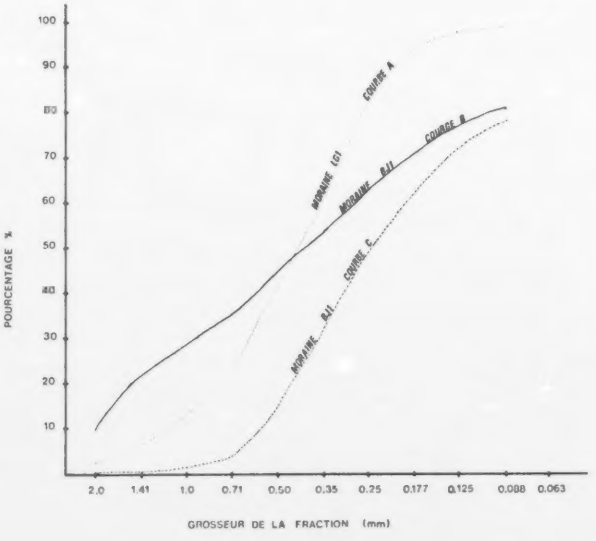


Figure 4 Courbes granulométriques des moraines LG1 et BJ1.

Sédimentologie des moraines

Dans l'ensemble, les moraines sont formées d'un till sableux contenant quelques galets et blocs. Les analyses granulométriques démontrent que le sable le plus fréquent est de grosseur moyenne (médianes entre 0,29 et 0,43) et que les fractions inférieures à 0,063 mm forment une classe modale en représentant 21,6% de l'ensemble. La grosseur moyenne des galets est de 9,6 cm alors que les blocs ne dépassent pas 60 cm de longueur et ils sont moins nombreux à l'intérieur de la moraine qu'en surface. Ceci implique soit le délavage de la moraine sous l'action des vagues, ou encore un apport de blocs par l'activité glacielle.

Trois courbes granulométriques permettent d'illustrer les trois types de sédiments rencontrés couramment dans les moraines de De Geer du champ Fort-George (figure 4). La courbe A a été établie à partir de sédiments prélevés à 30 cm seulement sous la surface de la moraine LG1. Elle représente un till remanié par les eaux de la Mer de Tyrrell. De

plus, elle démontre un matériel fait de sable moyen (médiane: 0,43 mm), dont le Qdphi de Krumbein est de l'ordre de 0,63. Enfin, la fraction fine ne représente que 1,1% de l'ensemble.

La courbe B a été établie à partir de sédiments prélevés à 65 cm sous la surface de la moraine BJ1 et se caractérise par une fraction fine représentant 19,2% de l'ensemble. Cette courbe décrit un till sableux qui est le matériel le plus fréquemment rencontré dans les moraines. Il est à noter que visuellement, il n'y a pas de différence entre les sédiments remaniés par l'eau et non remaniés.

La courbe C illustre un échantillon prélevé dans une strate sableuse, sans galets, située dans la moraine BJ1, à 205 cm sous la surface. La courbe montre un matériel composé de sables fins (médiane: 0,25 mm) et son Qdphi de Krumbein est de l'ordre de 0,93. Cet ensemble est donc mal trié comparativement à celui de la courbe A et il représente un matériel morainique moins fréquent que le till sableux de la courbe B. Peut être que l'eau a joué un rôle plus important dans sa mise en place. Ce type de sédiment ne s'observe que sur le côté distal des moraines. Enfin, dans la même moraine que la courbe C, une autre analyse a donné un Qdphi de Krumbein de 0,45, c'est-à-dire un triage un peu plus prononcé.

Conclusion

Les courbes B et C représentent un matériel originel mis en place, très certainement au front du glacier dans la Mer de Tyrrell. Par sa teneur en éléments fins, il se situe, au point de vue granulométrique, entre les eskers, qui en sont dépourvus, et les drumlins qui en sont largement pourvus, ce qui s'exprimerait par le fait que la glace et l'eau ont été très actifs dans leur genèse, sans que l'un domine l'autre.

La comparaison des courbes granulométriques dans les différents champs de moraines de De Geer, basée sur l'échantillonnage de plusieurs moraines devrait permettre de savoir si les sédiments se ressemblent d'un champ à l'autre. En tenant compte du contexte géomorphologique propre à chacun des champs, on devrait être alors en mesure de faire une relation entre les sédiments et la géomorphologie régionale, pour en déduire le contexte de la mise en place des moraines de De Geer.

Remerciements

Je désire remercier le Dr Bernard Lauriol qui m'a dirigé dans cette étude. Je suis également redevable à Luc Carrier, Marc-André Saia et Clément Prévost du département de géographie de l'Université d'Ottawa, qui m'ont aidé dans la cueillette de données sur le terrain. Je m'en voudrais d'oublier le Ministère des Affaires Indiennes et du Nord, le C.R.S.N.G. et Défi 86, qui nous ont fournis leur appui financier.

Références

Andrews, J.T., 1963, Cross-valley moraines of the Rimrock and Isortoq river valleys, Baffin Island, N.W.T. A descriptive analysis. Geographical Bulletin, No. 19, pp. 49-77.

Beaudet, H., et Lauriol, B., 1983, Les moraines de De Geer de la côte est de la baie d'Hudson, ACFAS, Programme et Resumés, Québec, mai 1983.

Hardy, L., 1976, Contribution à l'étude géomorphologique de la portion québécoise des Basses Terres de la Baie de James, Thèse de doctorat, Université McGill, Montréal, 263 p.

Hardy, L., 1982, La moraine frontale de Sakami, Québec subarctique, Géographie physique et Quaternaire, Vol. 36, Nos. 1-2, pp. 51-61.

Hillaire-Marcel, C., Occhietti, S., et Vincent, J.-S., 1981, Sakami moraine, Québec: A 500-km-long moraine without climatic control, Geology, Vol. 9, pp. 210-214.

Hoppe, G., 1959, Glacial morphology and inland ice recession in Northern Sweden, Geografiska Annaler, Vol. 51, pp. 193-212.

Lee, H.A., Identification of De Geer moraines with examples from Quebec, manuscrit.

Mansikkaniemi, H., 1973, De Geer-moreenin Rakenteesta Turussa, Geologi, Nos. 9-10, pp. 97-101.

Shaw, G., 1944, Moraines of late Pleistocene ice fronts near James Bay, Québec, Transactions of the Royal Society of Canada, Section IV, pp. 79-85.

Sollid, J.L., and Carlson, A.B., 1984, De Geer moraines and eskers in Pasvik, North Norway, Striae, Vol. 20, pp. 55-61.

Vincent, J.-S., 1977, La Quaternaire récent de la région du cours inférieur de La Grande Rivière, Québec, Commission Géologique du Canada, Etude 76-19, 20 p.

Vincent, J.-S., and Hardy, L., 1979, The evolution of glacial lakes Barlow and Ojibway, Quebec and Ontario, Geological Survey of Canada, Bulletin 316, 18 p.

Vincent, J.-S., 1985a, Géologie des formations en surface, Réservoir La Grande 2, Québec, Commission Géologique du Canada, Carte 1590 A, échelle 1/100 000.

Vincent, J.-S., 1985b, Géologie des formations en surface, Radisson, Québec, Commission Géologique du Canada, Carte 1591 A, échelle 1/100 000.

Zilliacus, H., 1981, De Geer moranerna pa Replot och Bjorkon i Vasa skargard, Terra, 93:1, pp. 12-24.

A FIRST APPROXIMATION OF FROZEN SOIL CREEP, MELVILLE ISLAND, ARCTIC CANADA.

L. Bennett

Department of Geology, University of Ottawa, Ottawa K1N 6N5

Level: Ph.D.

Abstract

Perennially cryotic ground (i.e. permafrost) underlies most of Northern Canada. Although movements associated with the active layer (e.g. solifluction, cryoturbation, frost heave) are relatively well known, the deformation and creep of the underlying sediments is less well known. In theory, frozen soil creep is dependent upon 1) the ground ice content, 2) the ground thermal regime and 3) the sediment type.

Ice-rich colluvium derived from siltstones and sandstones of the Weatherall and Hecla Bay Formations near Rea Point, Melville Island, provide typical sediments for a field study aimed at documenting the nature, magnitude and controls

over frozen soil creep. Five slopes with various aspects and ranging from 3° to 10° in angle have been instrumented since May 1985 with a total of eleven inclinometer cases (3.0 m deep × 7.0 cm in diameter), twenty thermistor strings (to a maximum depth of 12.9 m.) and fifteen heavemeters (to 70 cm depth). A precision downhole slope inclinometer (Terra Technology MiniProbe MP 20) measures frozen soil creep to an accuracy of ± 0.02 cm. The measurement of objects inserted within the active layer and at the surface provide supplementary data. Preliminary results from one slope indicate maximum rates of frozen soil creep to be 0.196 cm · yr^{-1} just below the permafrost table and 0.099 cm · yr^{-1} at a depth of 1.0 m below the permafrost table.

Key words: Frozen soil creep, Melville Island, inclinometer, ground ice, creep, slope processes

Résumé

Le pergélisol (sol gelé en permanence) couvre une grande partie du Nord canadien. Bien qu'on connaisse assez bien les mouvements de la couche superficielle active du pergélisol (solifluxion, cryoturbation, gonflement du sol), les déformations et la reptation des sédiments sous-jacents sont moins bien élucidés. En principe, la reptation du sol gelé dépend: 1) de la teneur du sol en glace, 2) du gradient thermique du sol et 3) de la nature du sédiment.

Le colluvion à forte teneur en glace issu des schistes pélitiques et des grès des formations de Weatherall et de la baie Hécla, près de la pointe Rea à l'île Melville, constituent des sédiments typiques convenant à une étude sur place qui permettrait d'illustrer la nature, l'ampleur et les paramètres de la reptation d'un sol gelé. Depuis mai 1985 l'auteur a équipé cinq escarpements, d'aspects divers et d'inclinaisons allant de 3° à 10°, de onze inclinomètres en étuis de 3 m de hauteur par 7,0 cm de diamètre, de vingt cordes d'extensomètre (jusqu'à une profondeur maximale de 12,9 m) et de quinze sondes de gonflement (jusqu'à 70 cm de profondeur). Un inclinomètre de précision pour trou foré dans la pente (Terra Technology MiniProbe MP 20) mesure la reptation du sol gelé avec une précision de ± 0,02 cm. La mesure des déplacements d'objets placés au sein de la couche active et à la surface fournit des données complémentaires. Les observations préliminaires effectuées sur une pente montre que le taux maximum de la reptation du sol gelé est de 0,196 cm · an^{-1} juste au-dessous de la limite supérieure du pergélisol, et de 0,099 cm · an^{-1} à 1,0 m sous cette limite.

Mots-clés: reptation du sol gelé, île de Melville, inclinomètre, glace contenue dans le sol, mouvements de pente.

Introduction

Perennially cryotic ground (i.e., permafrost) underlies most of Northern Canada. Although movements associated with the active layer (e.g., solifluction, cryoturbation, frost heave) are relatively well documented, the deformation and creep of the underlying frozen sediments are less well known. The present study aims to document the nature, magnitude and controls over *in situ* frozen soil creep at Rea Point, Southeast Melville Island, N.W.T.

Soil creep occurs when gravity-induced stresses are of sufficient magnitude to cause soil deformation, but are not strong enough to produce shear failure. The creep of permafrost is dependent upon a number of interrelated processes (pressure melting, regelation, planar glide within ice crystals, ice crystal reorientation and recrystallization, etc.). These processes, in turn, are a function of (a) the ground ice content, (b) the ground thermal regime and (c) the sediment type.

Although many field studies have been concerned with creep processes in the active layer or in unfrozen soils (e.g., Egginton and French, 1985; Mackay, 1981; Mills, 1983), only a few studies consider the creep of frozen sediments (e.g., Giardino *et al.*, 1984; Savigny, 1980) and few laboratory tests have been conducted at temperatures and strain rates usually experienced in nature (e.g., Sego and Morgenstern, 1983). Savigny (1980) measured the *in situ* creep of frozen sediments in the Mackenzie Valley. His study indicates that measurable ice creep occurs in "warm" permafrost but does not suggest how widespread the process may be. The present study, undertaken in the "cold" permafrost of the high Arctic, attempts to give an indication of the ubiquitousness of this process.

The creep of ice in glaciers is well known. Ice acts virtually as a plastic and requires no yield stress prior to deformation. Tsytovich (1975) demonstrates that ice-rich frozen soils act as a plastic as well, although a certain yield stress is required to initiate the process. This yield stress decreases with increasing temperature. Shusherina and Bobkov (1978) suggest that a continuum of processes exists between ice-rich soils and ice-poor soils. Nickling and Bennett (1984) show that an exponential increase in creep strength (that is, a decrease in creep rate) occurs as sediments change from very ice-rich (as in ice glaciers) through moderately ice-rich (as in rock glaciers), to ice-poor. The latter sediments will creep when saturated by water, as the result of freeze-thaw, or upon wetting and drying.

Study area

Field measurements upon frozen soil creep have been carried out near Rea Point (75°22'N, 105°45'W), Eastern Melville Island, N.W.T. since 1984 (Figure 1). The terrain consists of flat to gently sloping surfaces extending up to low altitude ridges or hills.

The ridges trend in an east-west direction reflecting the bedrock geology which consists of well folded clastic rocks of the Melville Island Group. Test sites are located on sediments of both the Hecla Bay Formation and the Weatherall Formation. The Weatherall Formation consists primarily of shales, siltstone and fine-grained sandstone. The Hecla Bay Formation consists of fine to medium-grained, well sorted, quartz sandstone (Embry and Klovan, 1976).

Cryogenic weathering of these weakly lithified sandstones, siltstones and shales has led to the development of considerable quantities of fine sand and silt which make up the cold (mean annual ground temperature −17.0°C), ice-rich permafrost soils typical of Melville Island (Stangl *et al.*, 1982). The active layer averages about 60 cm in thickness though at some locations it extends only 20 cm below the surface.

The greatest concentrations of ice in these soils are found at 1) the base of the active layer, 2) the colluvium-residuum contact and 3) the residuum-bedrock contact (French *et al.*, 1986, in press; Stangl et al., 1982). In the Weatherall

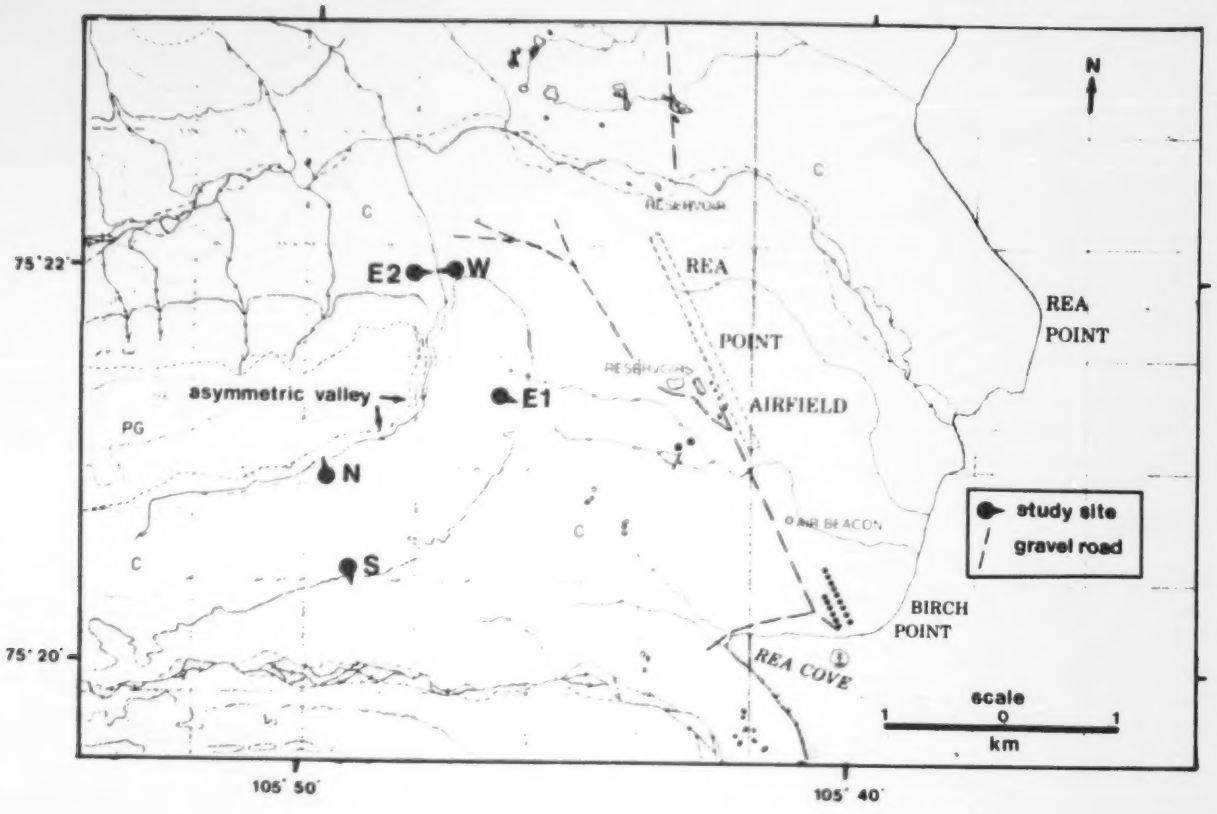


Figure 1. Study area and study site locations.

Formation, the colluvium consists primarily of silts and silty gravels and volumetric ice content averages from 60–75% and ranges from 50 to 100%. Since the colluvium-residuum boundary is found between 60cm to 180 cm depth, significant volumes of ice-rich, potentially mobile soils are located at or just below the frost table. In contrast, little visible ice is observed in the Hecla Bay Formation sediments.

Five slopes, each of different aspect and/or angle, have been instrumented in order to measure frozen soil creep (Figure 1). These include: 1) 3° north and south-facing slopes (N and S) approximately 5 km west of Rea Point, 2) 10° east and west-facing slopes (E2, W) in a small valley NW of the Rea Point camp, and 3) a 5° east-facing slope (E1) overlooking the Rea Point camp. In total, there are 11 instrumented locations: five at W, two each at E1 and E2 and one each at N and S.

Instrumentation

The instrumentation system involves thermistors, heavemeters and a downhole slope inclinometer. Further information is obtained by the measurement of objects inserted within the active layer and by the measurement and photography of marked pebbles on the ground surface. Readings are taken at least four times a year in order to assure some understanding of the relationships between the ground thermal regime, ground ice content and soil structure.

Twenty multi-thermistor cables (±.1°C accuracy) are used to measure soil temperatures. At each instrumented location (I), the cables extend to 2.5 m depth. Most thermistors are concentrated between 20 and 95 cm depth in order to present an accurate picture of the ground thermal regime at the critical permafrost-active layer interface. Thermistors are located 25 cm apart or more at greater depths. The thermistor readings demonstrate the potential for frozen soil creep. Since creep is primarily the result of water within frozen sediments, it is less likely to occur as soils become increasingly colder.

One thermistor cable was installed to give a temperature profile to a depth of 12.9 m. This cable enables the comparison between permafrost temperatures in the Rea Point area with other localities on the island, and elsewhere.

Fifteen 4-tube telescoping heavemeters were installed at the locations to measure frost heave. Preliminary temperature data indicates that the average depth to frost table is 60 cm. Thus, the heavemeters are designed to measure frost heave at depths of 15, 45 and 55 cm (although the thaw was just over 45 cm in 1985). The heavemeters give information concerning the degree of ice segregation (ice lense formation) and thus, vertical deformation stresses within the soil. This, in turn, provides information concerning potential surficial frost creep.

The inclinometer system consisting of 1) PVC grooved casing, 2) inclinometer, 3) cable and 4) readout unit, is designed to measure downslope movement of the ice-rich permafrost and active layer soils. It is hoped that, with readings taken throughout the year, it will be possible to differentiate between 1) permafrost creep, 2) differential shearing at the freezing plane, 3) frozen active layer soil creep, 4) soil creep and 5) gelifluction. The system is capable

of detecting changes in downslope configuration of slope soils to 0.02 (±0.01) cm over a 60 cm vertical distance.

On each slope a number of marked pebbles and Young's pits (Young, 1960) provide data complementary to that of the inclinometer system. While the inclinometer system generates site-specific data, the marked pebbles (200 to 500 pebbles on each slope) and the Young's pits provide knowledge of active layer deformation across the slope. The marked pebbles and Young's pits are employed to establish rates of movement in the seasonally thawed zone, and to identify any variability of movement across the slope.

Results

The results presented in this section are based upon data derived from study site E1-I2. Although the data suggest certain trends, more data are required to confidently project the results over the long term.

Table 1 is a compilation of inclinometer measurements taken four times over a period of one year. The inclinometer casing was installed in the spring of 1985 and solidly frozen in place by August of that year. Thermistor readings indicated that, although the ground thermal regime was initially disturbed by drilling, temperatures had returned to normal by August 6 when the initial inclinometer measurements were made. Further readings were taken on October 30, 1985, April 22 and July 3, 1986.

The data indicate that significant frozen soil deformation occurred between August 6, 1985 and October 30, 1985. This corresponds with the time of year when surface and near-surface temperatures reach the annual maximum (see Table 2). The active layer (10 cm depth) showed downslope deformation of 0.147 cm. The permafrost at 70 cm depth experienced downslope creep of 0.048 cm (about one-third of the near-surface rate). However, it is possible that active layer creep was initiated prior to August 6. At 70 cm, the soil temperatures were probably not warmer than −1.5°C.

TABLE 1
Results of inclinometer measurements taken at site E1-I2 between August 6, 1985 and July 3, 1986.

	Date Measured			
	Aug 6/85	Oct 30/85	Apr 22/85	July 3/86
Depth (cm)	Initial* Reading (cm)	Difference⁺ (cm)	Difference⁺ (cm)	Difference⁺ (cm)
10	12.817	0.147	0.196	0.163
70	9.261	0.048	0.079	0.069
130	5.987	0.003	0.018	0.018
195	2.870	0.003	0.010	0.018
285	0.0	—	—	—

*Difference between points along a vertical plane from casing base and actual casing position.
⁺Differences in the casing position (and hence movement) between measurement dates

Between October 30, 1985 and April 22, 1986, downslope deformation was measured at a depth of 130 cm. A similar deformation was measured at 195 cm depth between April 22 and July 3, 1986. At these depths, soil temperatures did not exceed −8.3°C (too cold to anticipate traditional creep associated with pressure-melting of *in situ* ice). It is suggested that tensile stresses resulting from rapid cooling of frozen sediments produces the limited movement of soils observed at some sites beween October and April.

TABLE 2
Ground thermal data at site E1-I2 between July 25, 1985 and July 3, 1986.

	Temperature Readings (°C) Measured On				
Depth (cm)	July 25/85	Aug 6/85	Oct 30/85	Apr 22/86	July 3/86
20	+ 0.5	+0.5	−17.0	−24.5	− 1.1
32.5	− 0.4	−0.2	−16.1	−25.1	− 2.2
45	− 1.2	−1.0	−15.4	−25.4	− 3.2
57.5	− 1.9	−1.7	−14.6	−25.6	− 4.3
70	− 2.4	−2.1	−16.1	−25.6	− 5.1
82.5	− 3.1	−2.8	−13.4	−25.9	− 6.0
95	− 3.7	−3.3	−12.9	−26.0	− 6.7
120	− 4.9	−4.4	−12.2	−26.1	− 8.3
145	− 6.2	−5.5	−11.6	−26.1	− 9.8
170	− 7.3	−6.5	−11.2	−26.0	−11.2
195	− 8.3	−7.5	−10.9	−25.6	−12.3
240	−10.0	−9.0	−10.5	−25.3	−14.0

Heavemeter results for site E1-I2 (Table 3) indicate that the minimum surface heave was 21.0 mm. It is possible that frost heave may have reduced the recorded soil creep by initiating vertical soil stresses on the casing in the active layer during freeze-up. During thaw, the soils (and casing) would subside, settling in a position slightly downslope (frost creep). This may explain the higher value of creep deformation recorded July 3, 1986 as compared with October 31, 1985 at the 10 cm depth. Alternatively, soil temperatures are warm enough by July 3, 1986 that a second season of creep may have begun (either as saturated soil creep or frozen soil creep within the active layer). However, since creep values are also higher at 70 cm depth on July 3, 1986, it is possible that sediments are again expanding as they become warmer and upslope (i.e., near surface) compressive stresses are acting on both the soils and inclinometer casing.

TABLE 3
Heavemeter data at site E1-I2 between October 31, 1985 and July 3, 1986.

Data Measured	Oct 31/85	April 22/86	July 3/86
	(mm)	(mm)	(mm)
Surface Heave	3.0	21.0	−6.0
Heave of Tube 4 (15 cm depth)	0.0	0.0	3.0
Heave of Tube 3 (45 cm depth)	6.0	0.0	1.0
Heave of Tube 2 (55 cm depth)	1.0	1.0	1.0

The heavemeter results at this site are somewhat ambiguous, possibly due to the binding of one of the telescoping tubes. In general, it is clear that the effects of frost heave are most significant in the near-surface sediments. Since the active layer did not exceed 45 cm, both of the lowermost tubes remained frozen in place. It is not clear why the outer tube remained stable while the surface heaved 21.0 mm.

Conclusions

In this paper, just one of eleven instrumented sites in the Rea Point vicinity is discussed. The results, therefore, must be treated with caution.

Frozen soil creep occurs when gravity-induced stresses are of sufficient magnitude to cause soil deformation. This process is significantly affected by sediment type, ice content and soil temperatures. At site E1-I2, the silty sediments assure high ice contents and the near-surface ground temperatures are sufficiently warm to induce frozen soil creep.

Preliminary data indicates that at 10 cm depth downslope deformation (i.e., gelifluction) attains rates of approximate 0.15 to 0.20 cm/yr^{-1}. Frozen soil creep rates of 0.05 to 0.08 cm/yr^{-1} were measured at 70 cm depth, approximately 25 cm below the depth of thaw in 1985–1986. It appears that measurable frozen soil creep is probably limited to within 50 cm of the frost table. The limited soil deformation measured at depths of 130 cm and 195 cm is likely associated with the thermal expansion and contraction of near-surface sediments undergoing rapid fall cooling and spring warming.

Acknowledgments

This research is being supported by grants from the Natural Sciences and Engineering Research Council (Grant A8367 — H.M. French), and the University of Ottawa Northern Research Group. Logistical and other support has been generously provided by Panarctic Oils Ltd., Calgary.

References

EBA Engineering Consults, 1983. Geotechnical evaluation of ditching trials, Rea Point, N.W.T. Report submitted to Nova Corp Engineering Services Ltd., April 1983.

Egginton, P.A. and H.M. French, 1985. Solifluction and related processes, Eastern Banks Island, N.W.T. Canadian Journal of Earth Sciences, 22:1671–1678.

Embry, A. and J.E. Klovan, 1976. The Middle-Upper Devonian clastic wedge of the Franklinian geosyncline. Bulletin of Canadian Petroleum Geologists, 24:485–639.

French, H.M., L.P. Bennett and D.W. Hayley, 1986. Ground ice conditions near Rea Point and on Sabine Peninsula, Eastern Melville Island. Canadian Journal of Earth Sciences, 23: in press.

Giardino, J.R., J.F. Shroder, Jr., and M.P. Lawson, 1984. Tree-ring analysis of movement of a rock glacier complex on Mount Mestas, Colorado, U.S.A. Arctic and Alpine Research, 16:299–309.

Mackay, J.R., 1981. Active layer slope movement in a continuous permafrost environment, Garry Island, Northwest Territories, Canada. Canadian Journal of Earth Sciences, 18:1666–1680.

Mills, H.H., 1983. Clast fabric strength in hillslope colluvium as a function of slope angle. Geografiska Annaler, 65A:255–262.

Nickling, W.G. and L. Bennett, 1984. The shear strength characteristics of frozen coarse granular debris. Journal of Glaciology, 30(106):348–357.

Savigny, K.W., 1980. *In situ* analysis of naturally occurring creep in ice-rich permafrost soil. Unpublished Ph.D. thesis, University of Alberta, 439 p.

Sego, D.C. and N.R. Morgenstern, 1983. Deformation of ice under low stresses. Canadian Geotechnical Journal, 20:587–602.

Shusherina, E.P., and Yu P. Bobkov, 1978. Effect of moisture content on frozen ground strength. Technical Translation 1918, National Research Council, Ottawa, 19 p.

Stangl, K.O., W.D. Raggensack and D.W. Hayley, 1982. Engineering geology of surficial soils, Eastern Melville Island. In: The R.J.E. Brown Memorial Volume, Proceedings of the Fourth Canadian Permafrost Conference, Calgary, Alberta, 1981, 136–147.

Tsytovich, N.A., 1975. The Mechanics of Frozen Ground. McGraw Hill Book Co., New York, 426 p.

Washburn, A.L., 1980. Geocryology. John Wiley and Sons, 406 p.

Young, A., 1960. Soil movement by denudational processes on slopes. Nature, 188:120–122.

EARLY FAULTING IN THE NORTHERN LABRADOR TROUGH

Paul Budkewitsch[1], Normand Goulet and Henry S. deRomer[2]

Departement des Sciences de la Terre, Université du Québec à Montréal, Montréal, Québec H3C 3P8
[1]Present address: Department of Geological Sciences and J. Tuzo Wilson Research Laboratories, Erindale Campus, University of Toronto, Missisauga, Ontario.
[2]Department of Geology, Concordia University, Montreal, Quebec H3G 1M8

Level: P. Budkewitsch, Bachelor's

Abstract

The Labrador Trough is essentially characterized by deep ocean floor volcanic and platformal sedimentary rocks. The contact between the variable siliclastic deposits of the Chioak Formation (alluvial fan deposit) and the dolomitic Abner Formation (shallow water carbonates) represents a major north-south trending structural and geomorphological boundary. This marks the western limit of allochthonous rock units in the northern Labrador Trough. Detailed examination of this contact reveals a major thrust fault. Cataclastic and mylonitic textures are present in the footwall rocks of the Chioak Formation. Structural and stratigraphic evidence indicates a SW directed overthrusting of approximately 25 Kms of the hangingwall Abner Formation on top of younger Chioak units.

The Abner, formally thought of as the basal unit of the third depositional cycle, can now be correlated with the Denault dolomite of the second cycle.

Key words: Thrust fault, Tectonic, Northern Labrador Trough

Résumé

Le fossé du Labrador est constitué en gros par des roches sédimentaires de plate-forme continentale et des roches volcaniques de grand fond océanique. Le contact entre les sédiments siliclastiques variables de la formation Chioak (sédiments en cône alluvial) et la formation dolomitique Abner (carbonates déposés en eau peu profonde) constitue

une importante frontière structurale et géomorphologique orientée du nord au sud. Elle marque la limite occidentale des membres rocheux allochtones de la partie nord du fossé du Labrador. L'examen détaillé de ce contact révèle l'existence d'une grande faille de poussée. Des textures cataclastiques et mylonitiques sont présentes dans le mur de la formation Chioak.

Quelques formes structurales et stratigraphiques indiquent l'existence d'un chevauchement d'environ 25 km, orienté vers le sud-ouest, du toit de la formation Abner sur les membres plus jeunes de la formation Chioak.

Il est maintenant possible de corréler la formation Abner, qu'on considérait antérieurement comme le membre de base du 3e cycle de sédimentation, avec la dolomite Denault du second cycle.

Mots-clés: Faille de poussée, tectonique, Nord du fossé du Labrador.

Introduction

The northern part of the Labrador Trough was first explored by A.P. Low for the Geological Survey of Canada in 1893. During his epic voyage he recognized iron formations and sulfide deposits that were almost unnoticed for the next half century (Low, 1895). The discovery of iron ore deposits near Schefferville brought great economic interest to the region in the late 1940's and 50's. During this time, the Labrador Trough was the site of active exploration by mining companies as they pushed their search northward for iron, gold, silver and base metals. The necessity for geological base maps involved both the Quebec Department of Natural Resources and the Geological Survey of Canada: efforts that still continue.

This discussion deals with a part of the geology in the northern Labrador Trough south of Leaf Bay, about 100 km northwest of Kuujjuaq (figure 1). Refinements concerning the structure and stratigraphic relationships between two particular meta-sedimentary units are summarized and represent part of an ongoing study of the tectonostratigraphic framework in the northern Labrador Trough.

Regional geology

The Labrador Trough is the preserved portion of an early Proterozoic (1.6–2.5 Ga) fold belt which extends in a north — south direction for 1100 km from the west coast of Ungava Bay into Labrador (figure 1). For a comprehensive review on the geology of the Labador Trough, we refer the reader to Dimroth (1970).

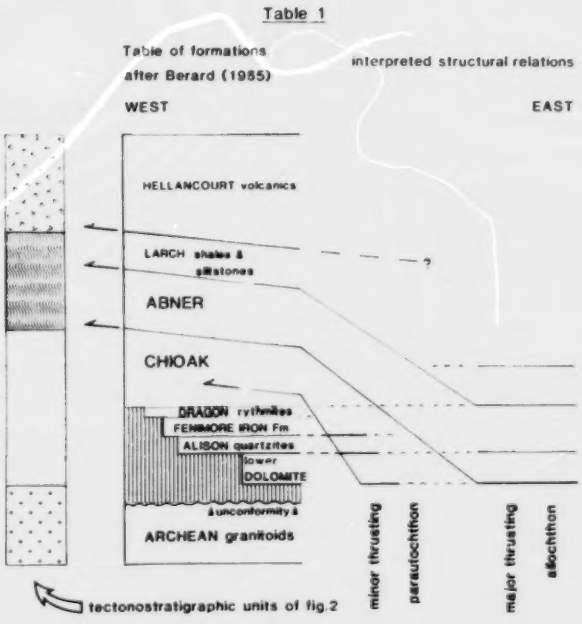
Sedimentary and volcanic rocks were deposited as an eastward thickening wedge above an older basement of Archean granites and gneisses. Subsequent deformation during the Hudsonian orogeny (approximately 1.7 Ga) confined the units between the ultra-stable Archean craton to the east and meta-stable Archean gneisses to the west. Presently, this narrow belt of meta-sedimentary and meta-volcanic rocks unconformably overlie Archean granites and gneisses to the west.

Local geology

This discussion deals with the structural and stratigraphic relationship between two major Aphebian (early Proterozoic) meta-sedimentary units of the Labrador Trough, namely the Chioak and Abner Formations. The Chioak rocks are included in the basal autochthonous — parautochthonous sedimentary unit and the Abner Formation is part of the newly defined allochthonous sedimentary package (figure 2). Table 1 illustrates the superposition of formations in the area and their revised stratigraphic positions as interpreted from structural evidence.

Figure 1. Location and general boundary of the Labrador Trough.

Table 1



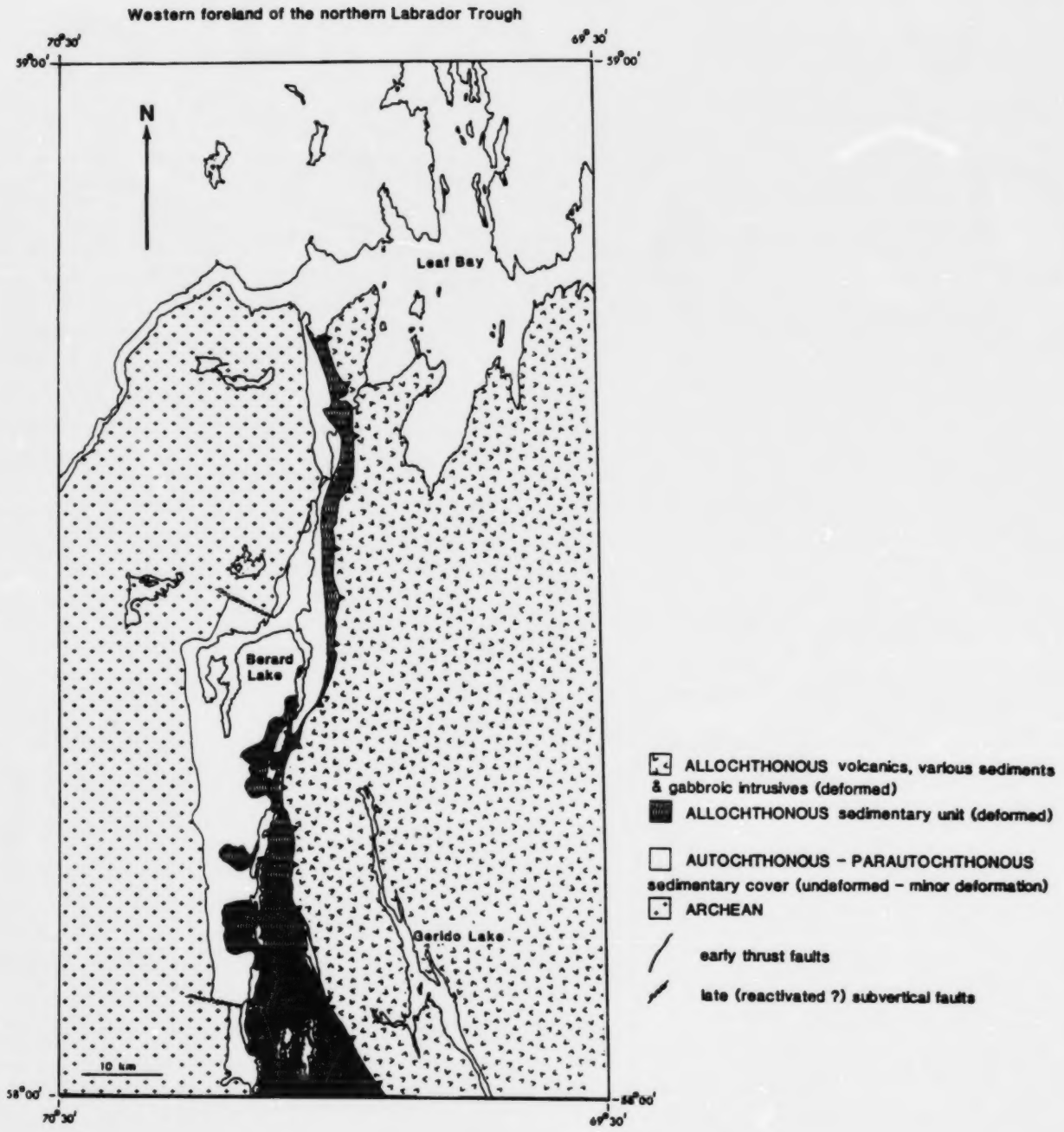


Figure 2. Simplified geological map of the study area showing the four major tectonostratigraphic boundaries.

1. Chioak Formation

The Chioak Formation is composed of a variety of sedimentary deposits including polymictic conglomerates with pebble to cobble size clasts derived from the erosion and reworking of all underlying formations. Most conglomerates are quite friable and individual clasts can easily be removed from the surface of the exposures. Generally, the Chioak is represented by 10 cm to metre scale beds of fine to coarse grained arenites interbedded with thinner siltstone or mudstone layers. Most of the Chioak sequence is flat lying or gently dipping to the east. It is interpreted as an erosional unit of shallow marine and possibly fluvial environments.

2. Abner Formation

The Abner Formation consists of laminated dolomites or calcitic dolomites, intraclastic dolomites and dolomitic sandstones. Strong folding and evidence of later cross-folds indicate that this unit is more deformed than the underlying units. In general, bedding dips gently to moderately eastward, giving rise to a remarkable cuesta morphology. South of Bérard Lake (figure 2), a series of prominent cuestas consisting of dolomitic Abner rocks dominate the landscape. These features have steep west facing scarps and reach elevations of 50 to 70 metres above the surrounding valley floor. Although outcrops stand out in relief, they also display pronounced effects of solution phenomena. Exposed corners of intersecting joint and bedding planes are well rounded. Quartz veinlets and chert bands stand out in relief as blades, often as much as 3 cm high. Trellis networks of intersecting quartz veins are characteristic of the Abner.

The weathered surfaces are dusty in appearance, commonly chamois or light-gray in color. Some bands range in color from chocolate-brown to various shades of orange-brown and even red. A particular fire-orange lichen is noticed preferentially growing on these dolomitic rocks.

The finely laminated nature of the unit and the presence of an algal stromatolite facies suggest that this unit was deposited in a low energy environment of a shallow water platform.

The nature of the Chioak — Abner contact

The contact between the two formations dips gently to the east and has been previously described by Bérard (1959, 1965) as a concordant contact with occasional intercalations. Recent work however, has shown the Abner Formation to overlie the Chioak in fault contact, often marked by a distinct angular discordance (Clark, 1979; Budkewitsch *et al.*, 1986). The transition from the Chioak to the Abner is a gradational zone of intense deformation. Cataclastic and mylonitic textures are observed in this zone which is considered characteristic of shearing and intense deformation.

Detailed examination of the contact zone revealed various thrust-fault structures such as imbricate stack arrays, slickenside-striation marks and drag-folds as kinematic indicators which all support a southwest direction of transport (Budkewitsch *et al.*, 1986). Overriding the Abner Formation to the west is the Larch Formation where structurally repeated units of the Abner occur as fault bounded slivers of dolomite.

On a regional scale it has been suggested by Goulet (1985) that the Chioak — Abner fault zone represents the sole thrust along which Abner dolomites were transported westward for distances in the order of 25 km. This folded sedimentary group west of the fault zone is therefore not positioned in situ with respect to the original location of deposition as previously believed. Relatively less deformed stratigraphic units below the fault zone, on the other hand, have not been displaced significantly, and often not at all. We therefore conclude that the Abner Formation is a structurally repeated unit and represents the western most allochthonous unit in the northern Labrador Trough.

Economic significance

The economic potential of the iron formations immediately south of Leaf Bay was evaluated by Consolidated Fenimore Iron Mines Ltd. during the early 1950's. No mining operation was ever developed in the region, and exploration eventually ceased. However a 15 km gravel road was constructed from Leaf Bay to Bérard Lake (figure 2).

In 1977, Imperial Oil Ltd. explored for uranium deposits, hosted in the conglomeratic facies of the Chioak, approximately 30 km south of Bérard Lake. Beyond the initial drilling stage, no further work has been completed. Kish and Tremblay-Clark (1978) reported promising concentrations of over 5000 ppm of uranium in the same area. It is suggested here that the proximity of the fault (previously unknown during the exploration) may have played a role in controlling the distribution of uranium. This invites further investigation or re-evaluation of the uranium occurrence in the Chioak host rocks.

Acknowledgments

We would like to thank the Ministère de L'Energie et des Ressources of Québec for financially supporting a three year project awarded to Normand Goulet and for permission to publish this paper. William Barclay kindly reviewed the manuscript and suggested improvements.

This work is part of a B.Sc. thesis,for which the author (Paul Budkewitsch) was partly supported by the Ministry of Indian and Northern Affairs. During the writing of this paper, the author was also supported by an NSERC grant awarded to P.-Y. Robin of Erindale.

References

Bérard, J. 1959. Géologie de la Région du Lac aux Feuilles, Nouveau Québec. Unpublished Ph.D. thesis, Laval University, Québec.

_____ 1965. Berard Lake Area, New Quebec; Department of Natural Resources; RG-111.

Budkewitsch, P., Goulet, N. & deRömer, H.S. 1986. Evidence for a western allochthon in the northern Labrador Trough, New Quebec. Canadian Tectonics Group 6th annual meeting, Sudbury, Ontario, Prog. Abs.

Clark, T. 1979. Région du Lac Napier, Territoire du Nouveau Québec; Ministère des Richesses Naturelles, Québec; DPV-452.

Dimroth, E. 1970. Evolution of the Labrador Geosyncline. Bull. Geol. Soc. Amer., 81. 2717-2742.

Goulet, N. 1985. Etude Tectonique et Stratigraphique de la Partie Nord de la Fosse du Labrador, Région de la Baie aux Feuilles et du Lac Bérard; Ministère de l'Energie et des Ressources, Québec; (sous presse).

Kish, L. & Tremblay-Clark, P. 1978. Geochemistry and Radioactivity in the Labrador Trough (56 00-58 30); Ministère des Richesses Naturelles, Québec; DPV-567.

Low, A.P. 1895. Report on exploration in the Labrador Peninsula along the Eastman, Koksoak, Hamilton, Manicuagan and portions of other rivers. Geological Survey of Canada annual report, new series VIII.

PRELIMINARY REPORT ON THE PETROLOGY AND GEOCHEMISTRY OF BASALTS OF THE PERMIAN ESAYOO FORMATION, SVERDRUP BASIN, CANADIAN HIGH ARCTIC

B.I. Cameron

Department of Geology, Dalhousie University, Halifax, Nova Scotia B3H 3J5

Level: Master's

Abstract

The Sverdrup Basin is a northeasterly trending structural depression containing up to 13 km of Lower Carboniferous to Tertiary marine and nonmarine sedimentary rocks, basalt flows, and diabase dykes and sills (Balkwill, 1978,1988). Volcanic rocks of the Sverdrup Basin occur interbedded with sedimentary strata of Lower Permian and Cretaceous age. The Permian volcanics of the Esayoo Formation (~265 Ma.) are part of a major igneous province, and have been studied by us on Axel Heiberg and northern Ellesmere islands. A greater understanding of the early geological evolution of the Sverdrup Basin can be achieved by investigating the stratigraphy, petrology, mineralogy, and geochemistry of these volcanic rocks.

Basaltic volcanic eruptions played an important role during the early stages of formation of the Sverdrup Basin. The Permian igneous event undoubtedly affected the thermal history of the basin, and consequently the subsidence rates and maturation of hydrocarbons. The thickest section of Esayoo volcanics was measured at Grumpy Glacier in the Van Royen Ridges where 22 basaltic flows of up to 300 metres cumulative thickness were encountered. Green alteration minerals and an aphyric texture are characteristic of the unique lithologies that compose the Esayoo Formation. Examination of chemical trends involving immobile trace elements such as Nb, Zr and Y allows the petrogenesis of the volcanic rocks to be studied despite modification of the whole rock chemistry due to secondary alteration.

Key words: Permian, Esayoo Formation, basalts, Sverdrup Basin, petrology, geochemistry, Ellesmere Island.

Résumé

Le bassin de Sverdrup forme une dépression structurelle allongée vers le nord-est et contenant, en épaisseur, jusqu'à 13 km de roches sédimentaires d'origine non marine, de coulées de basalte, de dykes et de filons-couches de diabase du Carbonifère ancien au Tertiaire. Les géologues se sont surtout intéressés aux roches sédimentaires pétrolifères et gazifères, alors que la géologie des roches ignées n'a presque pas été étudiée.

Les éruptions basaltiques ont joué un rôle important au cours des premières phases de la formation de ce bassin. Les roches volcaniques de la formation d'Esayoo du Permien (−290 Ma à −250 Ma) des îles d'Ellesmere et d'Axel Heiberg sont des basaltes non porphyriques, remarquables pour leur altération très poussée. La coupe verticale complète du basalte comprend 24 coulées, dont l'épaisseur totale est de 300 m. L'épaisseur des coulées de basalte décroît à mesure de leur éloignement de la bouche éruptive, tout comme leur quantité. Les laves en coussinets des crêtes Van Royen montrent un changement de faciès évoquant le passage de la phase d'éruption terrestre à la phase sous-marine.

L'auteur étudie la stratigraphie, la pétrologie, la minéralogie et la géochimie de ces roches pour un certain nombre de raisons: les phénomènes magmatique influencent les processus thermiques dans le bassin, et donc la vitesse de son affaissement et la bitumination des hydrocarbures; la présence d'épanchements de laves du Permien étaye l'hypothèse d'une formation de ce bassin au cours d'une grande extension de la lithosphère, pendant le Paléozoïque récent; enfin l'étude des oligoéléments et des isotopes contenus dans les laves de la formation d'Esayoo permettront de reconstituer l'évolution de la lithosphère et du manteau terrestre.

Mots-clés: Île d'Ellesmere, Permien, basalte, formation d'Esayoo, bassin de Sverdrup.

Introduction

Although intensive geological research has been focussed on the thick Late Paleozoic to Mesozoic sedimentary successions of the Sverdrup Basin, the majority of the igneous rocks in the Canadian Arctic remain virtually unstudied. The magmatic rocks of the Sverdrup Basin occur primarily within Lower Permian and Cretaceous strata. As a result of petrological studies of the younger Cretaceous and Tertiary igneous rocks (Clarke, 1970a; Clarke, 1970b; Clarke *et al.*, 1983; and Williamson, pers. comm.), the geological evolution of the North Atlantic regions has become more clearly understood. Consequently, the particular interest of this report is the basaltic eruptive sequences of the Permian Esayoo Formation on Axel Heiberg and northern Ellesmere islands.

During the past decade, a considerable research effort has been directed into the formation of sedimentary basins (McKenzie, 1978; Sclater and Christie, 1980; Keen, 1985). Overlooked in this research is the significant role basaltic volcanism plays in the development of passive continental margins and adjacent sedimentary basins. The magmatic events affect the thermal history of the basin, and therefore the subsidence rates and maturation of hydrocarbons.

Igneous rocks in the Canadian Arctic range in age from the Precambrian to the Tertiary, and thus provide one of the best opportunities to examine mantle evolution over a geological province. In summary, the unresolved problems pertaining to Permian igneous activity are its nature and petrogenesis, its effect on the early thermal history of the Sverdrup Basin, and its significance in the tectonic development of the Arctic region.

Regional geologic setting

The Sverdrup Basin is a northeasterly trending structural depression containing up to 13 km of Lower Carboniferous to Tertiary marine and nonmarine sedimentary rocks, basalt flows, and diabase dykes and sills (Balkwill, 1978). Figure 1 shows the geographical extent of the Sverdrup Basin in the Canadian Arctic Islands. The basin probably originated by graben formation in Late Mississippian time (Balkwill *et al.*, 1983). Strata of the Sverdrup Basin lie with angular unconformity on deformed Proterozoic and Lower Paleozoic rocks of the Franklinian Geosyncline (Thorsteinsson, 1974). A clastic wedge of Upper Cretaceous and Cenozoic age known as the Arctic Coastal Plain overlies the southwestern segment of the Sverdrup Basin.

Models for basin development

Sleep (1971) observed similarities between the subsidence experienced by many sedimentary basins and that of the ocean floor away from mid-ocean ridges. This was a major advancement in the understanding of basin formation as it incorporated sudden heating and conductive cooling of continental lithosphere into basin models. McKenzie (1978) suggested that the thermal anomaly and thinning of continental crust was caused by a major extensional event.

Geophysical studies of the western Arctic (Sobczak and Overton, 1984) indicate that continental crust of varying thickness floors the Sverdrup Basin. However, the processes that produced the crustal thinning and subsidence experienced by the basin are less well understood. Balkwill *et al.* (1983) noted that periods of rapid subsidence and widespread marine transgression were accompanied by episodic magmatic activity. A study of the stratigraphic relationship between the volcanics and sediments in the Sverdrup Basin should permit formulation of a model for Permian volcanism with respect to basin evolution and Late Paleozoic tectonic events.

Local geologic setting

Major unconformities mark the lower and upper boundaries of the Carboniferous and Permian rocks in the Sverdrup Basin, and thus represent a natural package of formations (Thorsteinsson, 1974). The predominant sedimentary rock types are carbonates, clastics, and evaporites of marine origin. Warm, deeper water conditions are implied by the occurrence of carbonates and evaporites exclusively in the Paleozoic of the Sverdrup Basin.

Figure 2 shows the Carboniferous and Permian stratigraphy of the Sverdrup Basin in the Canadian Arctic (Smith and Wennekers, 1977). The Permian Esayoo Formation typically overlies the carbonate-rich Nansen Formation, while a variety of overlying formations exist including the Van Hauen, the Assistance and the Trold Fiord Formations. Fossil evidence in the adjacent sedimentary rocks suggest an Artinskian age for the Permian volcanism (Thorsteinsson, 1974).

Field studies

Known occurrences of Permian volcanics in the northern Arctic were investigated in the summer field seasons of 1985 and 1986. Exposed sections of Permian basalts were examined at five localities on Axel Heiberg and northern Ellesmere islands (Figure 3).

On Axel Heiberg Island, poor exposure of Esayoo sections and problems with snow coverage made measurement of sections dificult. Fifteen samples were collected to characterize the chemical nature of the basaltic rocks. Stratigraphic sections of the four Ellesmere eruptive sequences with designated flow units and sample locations are shown in Figure 4. Six flow units were observed at Wood Glacier in the Blue Mountains of Ellesmere Island which measured 54.5 metres in total thickness. Four flow units comprised close to 30 metres of basalts measured at Ricker Glacier. The thickest section of those studied was discovered at Grumpy Glacier in the Van Royen Ridges where 22 flow units with a stratigraphic thickness of 305.5 metres were encountered. At the head of Hare Fiord, an eruptive sequence of 64.9 metres thickness consisted of seven basaltic flow units.

From hand sample descriptions of the Permian basalts of the Esayoo Formation, two observations were made on the nature of the volcanics. The Esayoo volcanics are characterized by their intensely altered state in outcrop, always appearing green in colour due to the abundance of serpentine and chlorite. Secondly, the basalts are almost exclusively aphyric with surprisingly few or no phenocrysts of plagioclase. These two characteristics define the unique lithologies that comprise the Esayoo Formation, and make their identification in the field relatively easy.

Trace element geochemistry

Powdered basaltic samples have been submitted for major and trace element analyses by X-Ray Fluorescence. Initial results on selected trace elements have been obtained for the two sections measured during the 1985 field season. The results are presented in Table 1.

Intensive alteration frequently characterizes older basalts, and is accompanied by significant changes in the rock chemistry. Understanding the petrogenesis of altered basalts is hindered by this modification of the primary mineralogy. Major elements, trace elements such as Ba, Rb and Sr, and some light rare earth elements are significantly modified, while Nb, Y and Zr, and the heavy rare earth elements are largely unmodified. The examination of the chemical trends exhibited by these immobile elements is essential in the understanding of the primary whole rock chemistry of the altered basaltic magmas.

Figure 5 shows a plot of Nb against Zr for the Esayoo volcanics collected at Ricker Glacier and Grumpy Glacier. A good correlation exists between these two immobile elements. Those samples containing high Zr also contain high Nb indicating a similar chemical behavior in the crystallizing flows. In general, the section at Ricker Glacier contains less Nb and Zr than at Grumpy Glacier, although the two sections comprise one population.

Figure 6 shows the relationship between Rb and Zr. These elements do not correlate as well which might be attributed to mobilization of Rb during alteration of the Esayoo basalts. Two separate trends of increasing Rb and Zr are observed in the binary plot.

Conclusions

The northern Canadian Arctic Islands have been found to comprise a major igneous province, yet the magmatic history

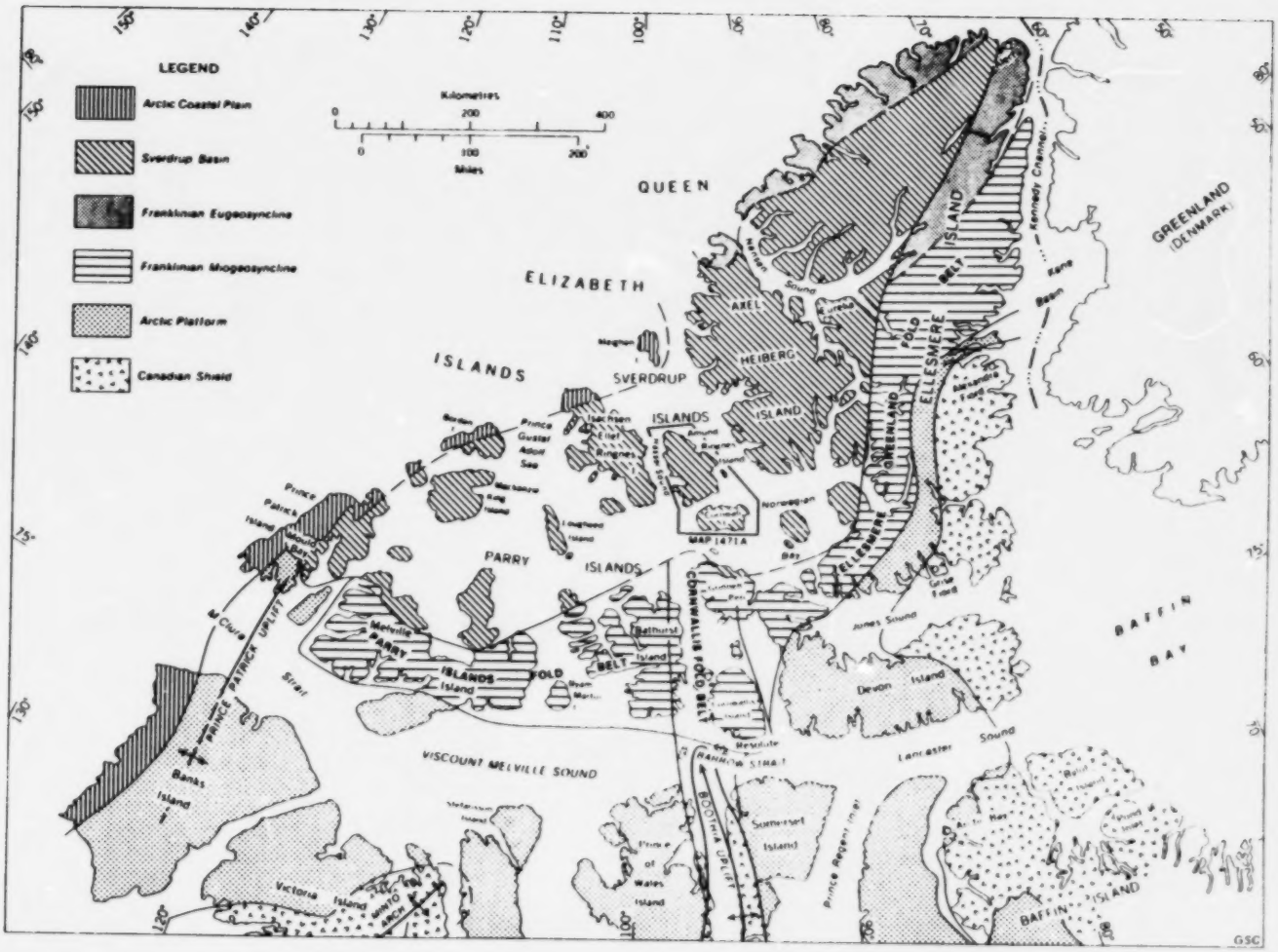


Figure 1. Geological provinces of the Canadian Arctic Archipelago (from Balkwill, 1983).

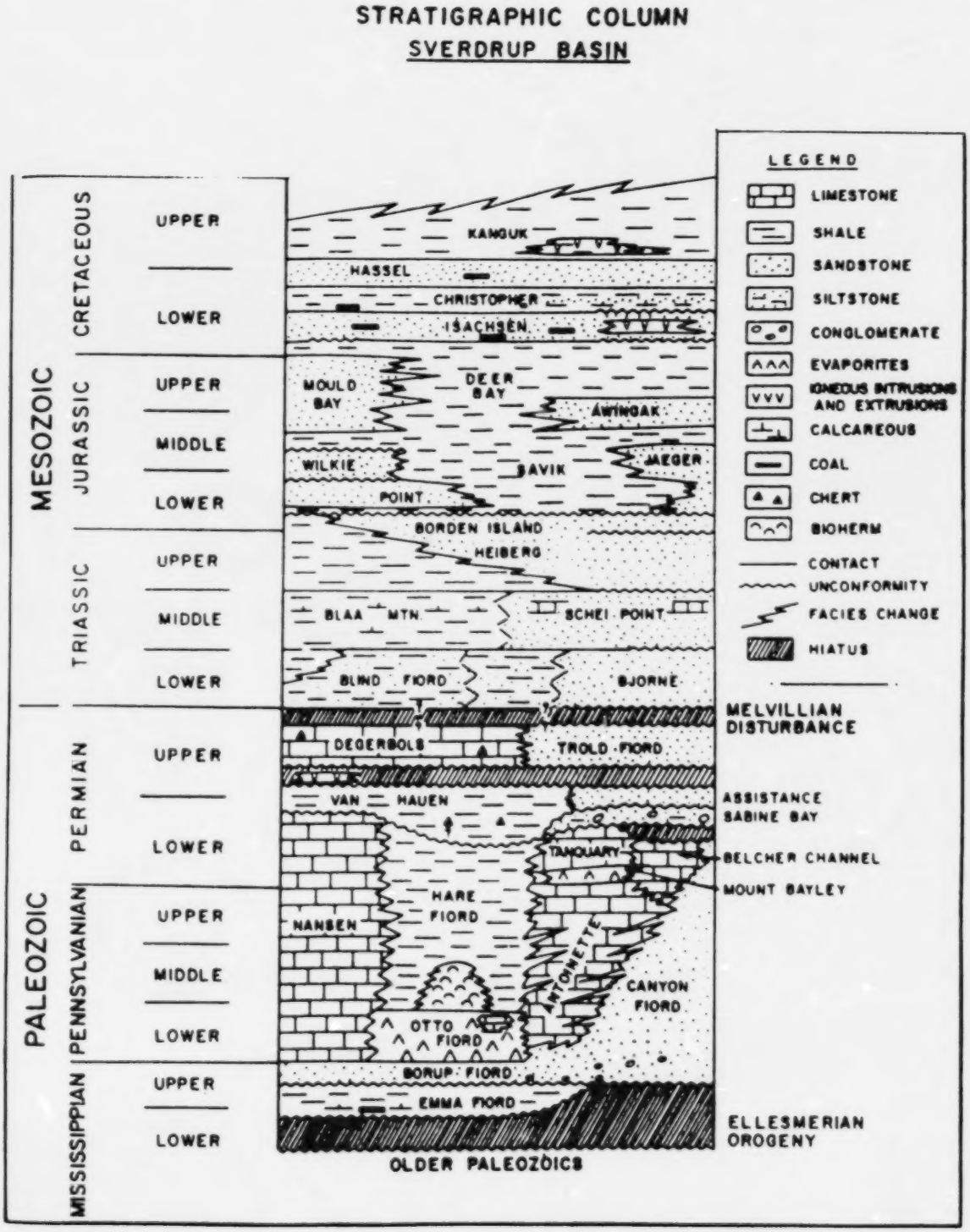


Figure 2. A stratigraphic section displaying the major formations of the Paleozoic and Mesozoic eras in the Canadian Arctic (from Smith and Wennekers, 1977).

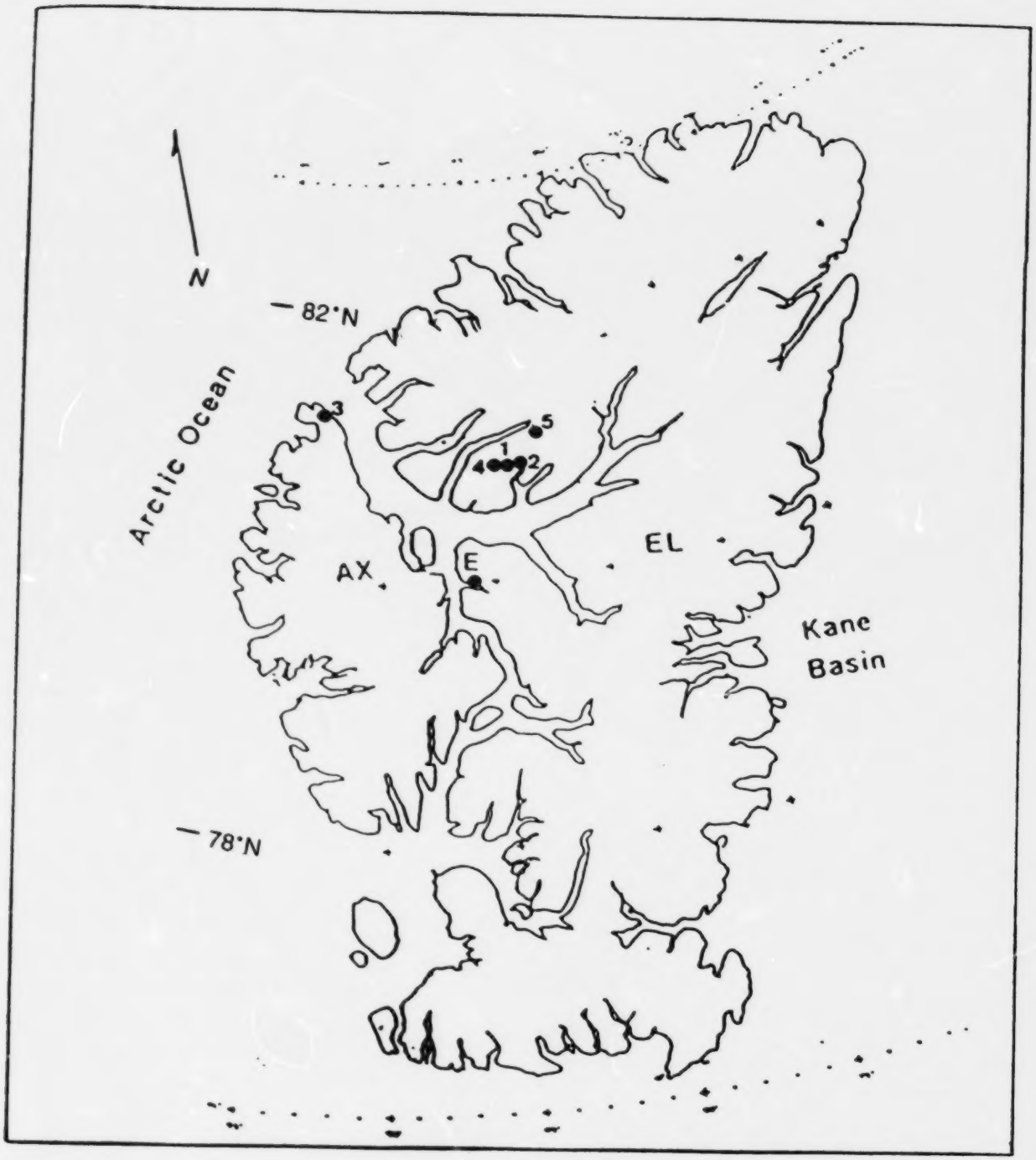


Figure 3 Section location map for the Permian Esayoo Formation. EL = Ellesmere Island, AX = Axel Heiberg Island, E = Eureka, 1 = Ricker Glacier, 2 = Grumpy Glacier, 3 = Cape Stallworthy, 4 = Wood Glacier, Blue Mountains, 5 = Head of Hare Fiord.

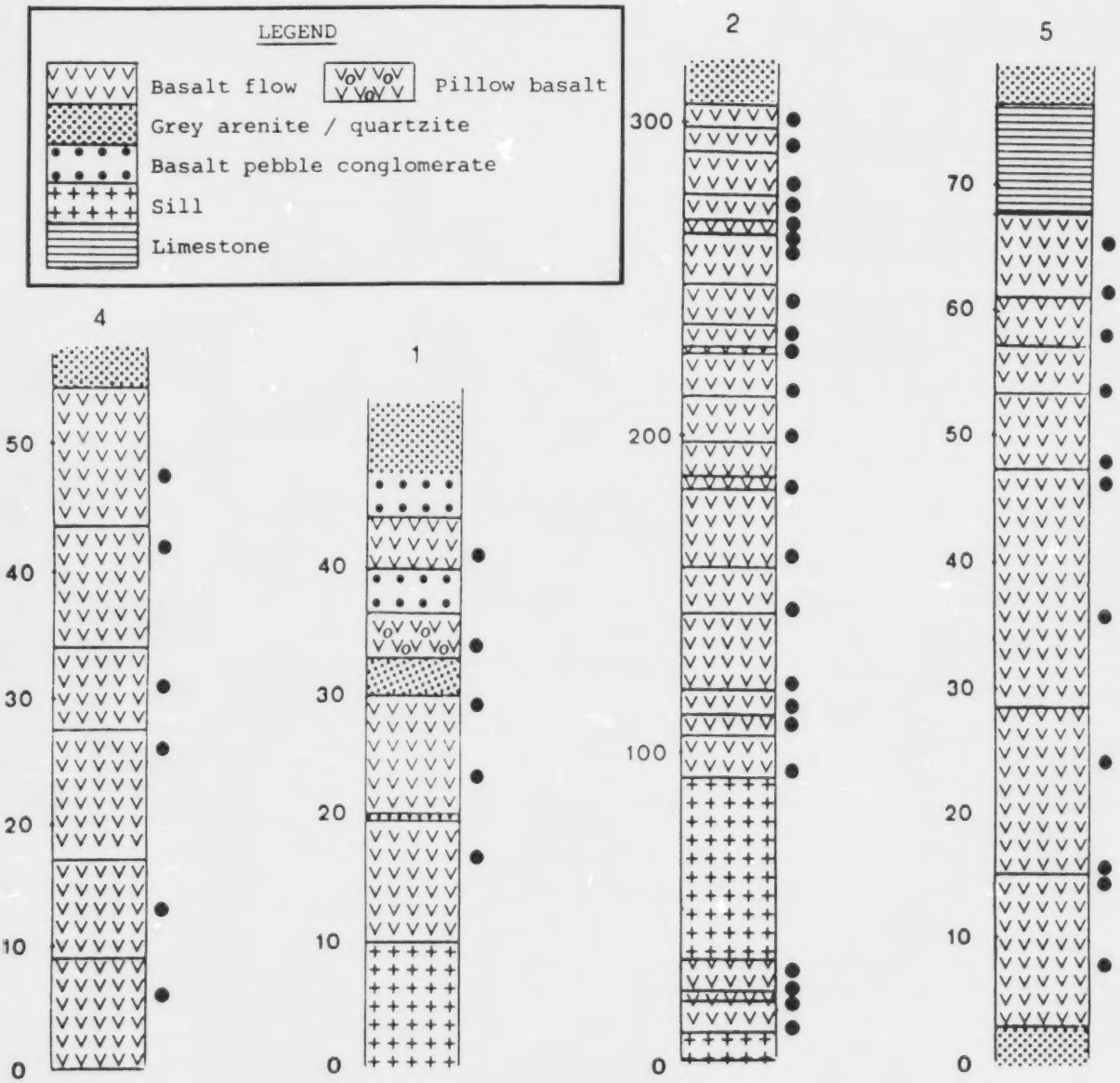


Figure 4 Four stratigraphic sections from Ellesmere Island showing thickness in metres and sample location by solid dot. Number at top of section corresponds to section in Figure 3. Note change of scale in Grumpy Glacier section (2).

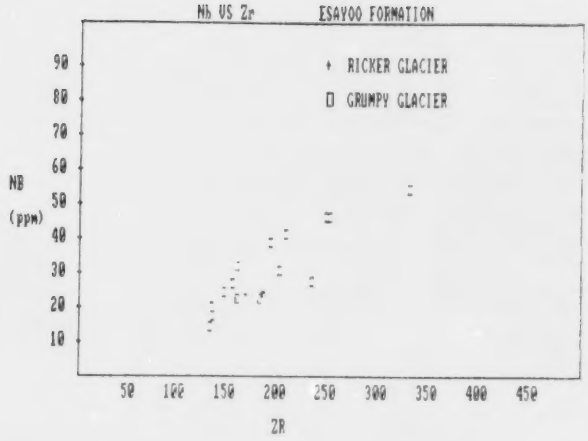


Figure 5. A binary plot of Zr against Nb for the Ricker and Grumpy Glacier sections. A reasonable correlation exists between these two immobile elements.

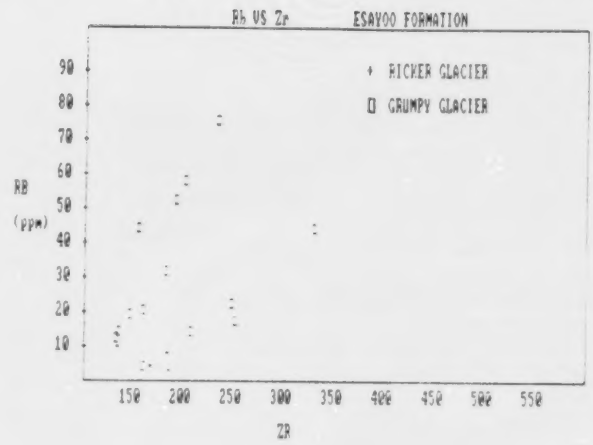


Figure 6 A binary plot of Zr against Rb for the Ricker and Grumpy Glacier sections of Ellesmere Island. Rb is a mobile element and shows a poor correlation with the immobile element Zr.

TABLE 1
Selected trace elements of Permian basalts of the Esayoo Formation in ppm.

	EL85-274	EL85-275	EL85-276	EL85-280		EL85-288	EL85-289	EL85-290	EL85-291	EL85-292	EL85-293
V	189	191	146	200	V	186	157	137	154	146	187
CR	325	302	397	279	CR	290	307	255	209	227	362
NI	88	73	217	85	NI	111	92	62	88	95	103
CU	19	10	8	34	CU	42	44	26	18	19	15
ZN	103	105	131	169	ZN	108	117	99	118	106	128
GA	23	26	17	24	GA	25	24	26	23	22	21
RB	4	8	3	10	RB	51	31	74	57	43	4
SR	241	250	130	400	SR	511	503	490	760	601	403
Y	22	22	22	19	Y	22	22	18	20	17	20
ZR	166	183	105	133	ZR	191	180	232	200	154	158
NB	23	24	24	21	NB	38	22	27	30	26	31
BA	255	128	641	141	BA	995	366	535	2005	656	316
PB	0	8	7	2	PB	7	6	8	1	6	2
TH	0	3	3	0	TH	3	0	3	0	0	0

	EL85-282	EL85-283	EL85-284	EL85-285	EL85-287		EL85-294	EL85-295	EL85-297
V	255	257	169	264	200	V	165	186	172
CR	227	274	359	361	261	CR	293	242	188
NI	72	83	82	101	109	NI	92	93	66
CU	30	24	28	3	11	CU	15	54	39
ZN	323	124	98	141	126	ZN	108	114	120
GA	25	23	21	23	23	GA	20	24	24
RB	22	17	12	14	43	RB	19	14	20
SR	187	131	247	269	808	SR	695	665	658
Y	21	24	18	24	21	Y	18	18	21
ZR	246	250	131	206	329	ZR	145	134	158
NB	45	45	14	40	43	NB	24	17	22
BA	145	163	70	162	1493	BA	2463	595	777
PB	8	0	9	4	6	PB	8	6	2
TH	4	0	0	0	4	TH	1	0	0

of the continental margin and the adjacent Sverdrup Basin has remained virtually untouched. During the Permian, significant volcanic activity produced basaltic flows of the Esayoo Formation. The primary mineralogy and consequently the whole rock chemistry of the Esayoo volcanics have been modified by a post-deposition alteration event. The Esayoo Formation is composed of unique lithologies characterized by an abundance of green alteration minerals (serpentine and chlorite) and its aphyric textue. Immobile trace elements are important in deciphering the petrogenesis of the Permian volcanics due to mobilization of the major elements and selected trace elements during secondary alteration.

Acknowledgments

I would like to express my thanks to Dr. G.K. Muecke who provided me the opportunity of having the Canadian Arctic as my field area. The companionship of Ms. Jennifer Bates in the field during the long, sunlit days of the Canadian Arctic is greatly appreciated. Her expert assistance made completion of the field work in one summer a reality. P.C.S.P. is thanked for their logistical support. The hospitality of the men at the Eureka Weather Station is recognized. To Barry Hough and all the field camps associated with P.C.S.P., I thank you for your entertaining communications on the radio.

References

Balkwill, H.R. 1978. Evolution of Sverdrup Basin. Bulletin of the American Association of Petroleum Geologists 62:1004-1028.

Balkwill, H.R. 1983. Geology of Amund Ringnes, Cornwallis and District of Franklin. Geological Survey of Canada Memoir 390, 76 p.

Balkwill, H.R., Cook, D.G., Detterman, A.F., Embry, A.F., Hakansson, E., Miall, A.D., Poulton, T.P. and Young, F.G. 1983. Arctic North America and Northern Greenland *in* The Mesozoic, B. Moullade, B. and Nairn, A.E.M., Eds. Elsevier:1-31.

Clarke, D.B. 1970a. Tertiary basalts dredged from Baffin Bay. Canadian Journal of Earth Sciences 12:1396-1405.

Clarke, D.B. 1970b. Tertiary basalts of Baffin Bay: possible primary magma from the mantle. Contributions to Mineralogy and Petrology 25:203-224.

Clarke, D.G., Muecke, G.K., and Pe-Piper, G. 1983. The lamprophyres of Ubekendt Ejland, West Greenland: products of renewed partial melting or extreme fractionation? Contributions to Mineralogy and Petrology 83:117-127.

Keen, C.E. 1985. The dynamics of rifting: deformation of the lithosphere by active and passive driving forces. Geophysical Journal of the Royal Astronomical Society 80:95-120.

McKenzie, D. 1978. Some remarks on the development of sedimentary basins. Earth and Planetary Science Letters 40:25-32.

Sclater, J.G. and Christie, P.A.F. 1980. Continental stretching: an explanation of the post-Mid-Cretaceous subsidence of the central North Sea Basin. Journal of Geophysical Research 85:3711-3739.

Sleep, N.H. 1971. Thermal effects of the formation of Atlantic continental margins by continental break up. Geophysical Journal of the Royal Astronomical Society 24:325-350.

Smith, J.H.S. and Wennekers, J.H.N. 1977. Geology and hydrocarbon discoveries of Canadian Arctic Islands. Bulletin of American Association of Petroleum Geologists 61:1-27.

Sobczak, L.W. and Overton, A. 1984. Shallow and deep crustal structure of the western Sverdrup Basin, Arctic Canada. Canadian Journal of Earth Sciences 21(8):902-919.

Thorsteinsson, R. 1974. Carboniferous and Permian stratigraphy of Axel Heiberg Island and western Ellesmere Island, Canadian Arctic Archipelago. Geological Survey of Canada Bulletin 224:115p.

POLLEN-SEDIMENT RELATIONSHIPS IN THE RUBY RANGE, YUKON TERRITORY

Ian Campbell

Ottawa-Carleton Centre for Geoscience Studies, Department of Geology, University of Ottawa, Ottawa, Ontario K1N 6N5

Level: Bachelor's

Abstract

Thick deposits of peat and gyttja, considered to be the best sediments for pollen anlysis, are completely absent at moderately high altitudes in the Ruby Range. Analysis of a sedimentologically variable deposit including layers of peat, silt, sand, and volcanic ash shows the expected distortion of the pollen spectra by the changing sedimentary environment. Subaqueous silts are dominated by regional pollen types, while sands deposited by rillwash show a higher proportion of local pollen coupled with very low pollen/sediment ratios, due to their high sedimentation rate. Comparison of this section with a control section in a uniform silt deposit demonstrates that, in spite of these distortions, deposits of this type can still be used for paleoclimatic interpretations.

Both profiles show a period starting prior to *ca.* 3840 BP and lasting until *ca.* 2450 BP, during which the regional climate was both warmer and drier than it is today. This is followed by essentially modern conditions until *ca.* 1655 BP, a return to the previous warmer and drier conditions between *ca.* 1655 BP and *ca.* 1380 BP, and finally the development of the modern regional climate.

Key words: Palynology, Ruby Range, Yukon, paleoclimate, Holocene.

Résumé

Les couches épaisses de tourbe et de vases lacustres, qu'on considère comme les meilleurs sédiments pour l'analyse pollinique, sont entièrement absentes aux altitudes modéréments élevées des monts Ruby. L'analyse d'une couche sédimentaire de composition variable, et comprenant des horizons de tourbe, de limon, de sable et de cendres volcaniques montre les disparités habituelles du spectre pollinique causées par un milieu de sédimentation changeant. Les limons fluviatiles contiennent surtout des pollens de types régionaux, alors que les sables déposés par ruissellement montrent une plus forte proportion de pollens locaux, en même temps qu'une très faible teneur pollinique due à l'accumulation rapide des sédiments. En comparant la coupe de ce sol avec une coupe-témoin de vases déposées uniformément, on remarque qu'en dépit de ses disparités, il est possible d'utiliser cette coupe variable pour élaborer des hypothèses paléoclimatiques.

Les deux profils commencent par une période allant des alentours de −3840 jusqu'à environ −2450, au cours de laquelle

le climat régional était plus chaud et plus sec que de nos jours. Les conditions actuelles prévalent ensuite jusqu'à environ −1655, où se produit un retour vers un climat chaud et sec qui dure jusqu'aux alentours de −1380, alors que se mettent en place les paramètres du climat actuel.

Mots-clés: Palynologie, monts Ruby, Yukon, paléoclimat, Holocène.

Introduction

The Ruby Range (Fig. 1) is a rugged, deeply dissected, plateau in the Southwest Yukon Territory. Valley bottoms are populated by spruce forest, on fluvioglacial or glaciolacustrine sediments. Peat bogs occurring in the valley bottoms are not suitable for detailed paleoclimate-oriented pollen analysis due to their location within, rather than at, the border of the spruce forest.

Above the tree-line, peat deposits become very rare, and are always interlayered with sand, silt, clay, and sometimes volcanic ash. Such deposits have long been considered unsuited to pollen analysis, on the assumption that the sedimentological changes would mask all but the most blatant climatic changes as reflected in the pollen spectra. Peat and gyttja are considered to be the most useful materials for palynology.

Gyttja does occur in the high-altitude lakes, but deposits have not been found thicker than five centimeters. Indeed, the only high-altitude deposits of uniform sedimentology which have been found are peats less than 38 cm thick, accumulations of volcanic ash up to 2 m in thickness, and a single deposit of uniform silt, 75 cm thick. This last deposit has been analysed, and serves as a control for the interpretation of a 150 cm deposit of alternating layers of *Dryas* peat, silt, sand, clay, and one correlatable layer of volcanic ash. Both pollen diagrams can be correlated with Bourgeois and Geurts (1983), and Heusser *et al.* (1985).

The validity of the pollen zones described from such a sedimentologically variable deposit is established here by 1) correlation with control sections, and 2) correlation of pollen spectra with sediment type. This paper emphasizes the preliminary results of pollen-sediment correlations.

Control section

The control section, named ALRG (Alaskite Rock Glacier), is a 75 cm accumulation of coarse silt in a small (two meter diameter) basin on a rock-glacier near Alaskite Creek (Fig. 1). The silt is derived primarily from the slope behind the rock-glacier, and is a subaqueous rather than aeolian deposit.

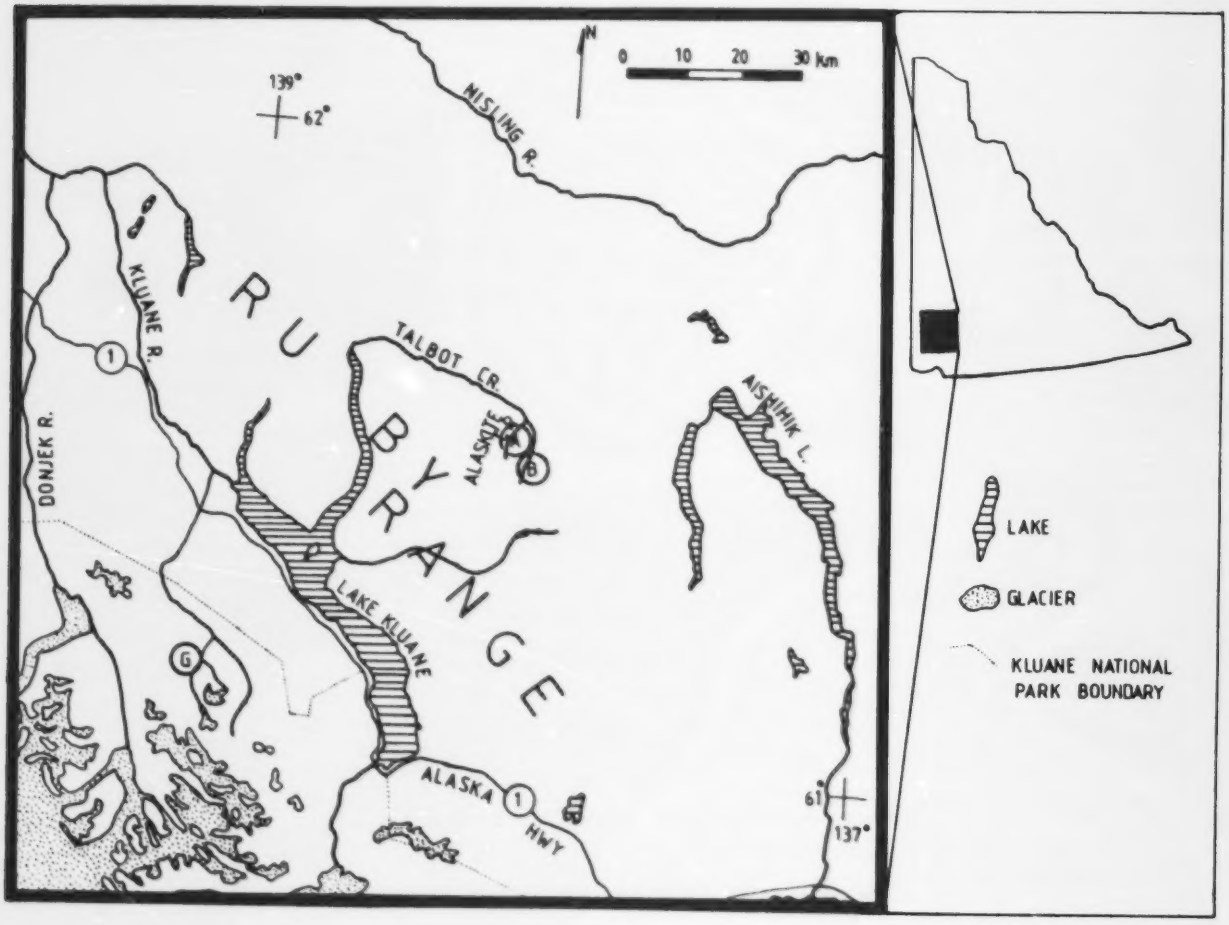


Figure 1. Location map.

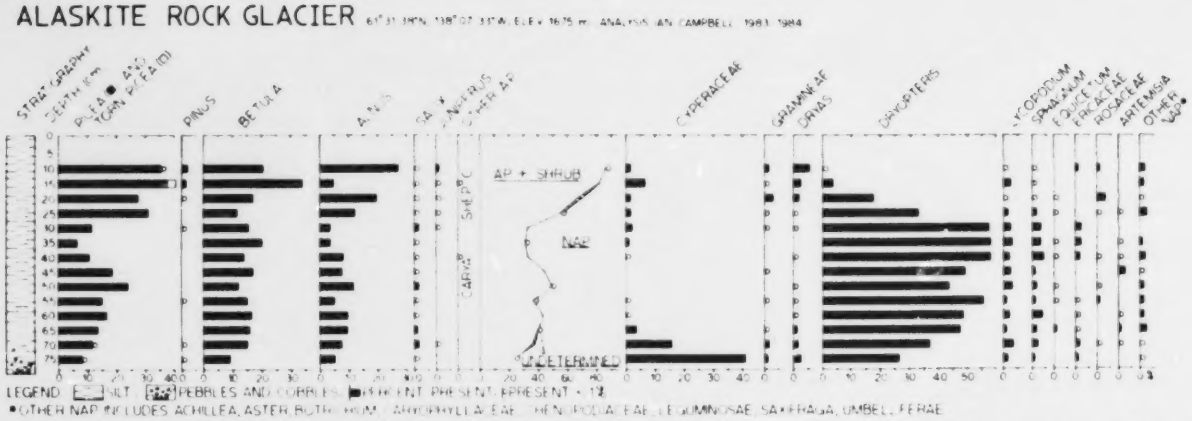


Figure 2. Alaskite Rock Glacier pollen diagram. Four zones can be recognized: samples 75–60; 55–45; 40–30; and 25–10. The strong *Dryopteris* and *Cyperaceae* curves are believed to represent edaphic rather than climatic changes.

No stratification is visible in the silt, although small pebbles become common near the base of the section (see left-hand column on figure 2).

The samples were processed using repeated HF attacks to remove silicates and acetylation (the chemically correct term for Erdtman acetolysis; Gray, 1965) to remove organic material.

The resulting pollen diagram (Fig. 2) shows a strong dominance by *Dryopteris* up to quite near the surface, and a strong dominance by *Cyperaceae* near the base. *Cyperaceae* also recover slightly with the decline of *Dryopteris* near the top. Both these taxa are taken to represent edaphic changes related to the silting-up of the basin, and so will not be considered for paleoclimatic purposes or for correlation with other diagrams.

The *Picea* curve lends itself to easy zonation by eye, with a rise in spruce values to 60 cm, followed by a peak between 55–45 cm, a distinct low from 40–30 cm, and a recovery reaching very high Picea percentages from 25–10 cm. These four pollen zones cannot represent local events, given that the site is well above the tree-line and the nearest spruce stands of any significance are three kilometers down-valley.

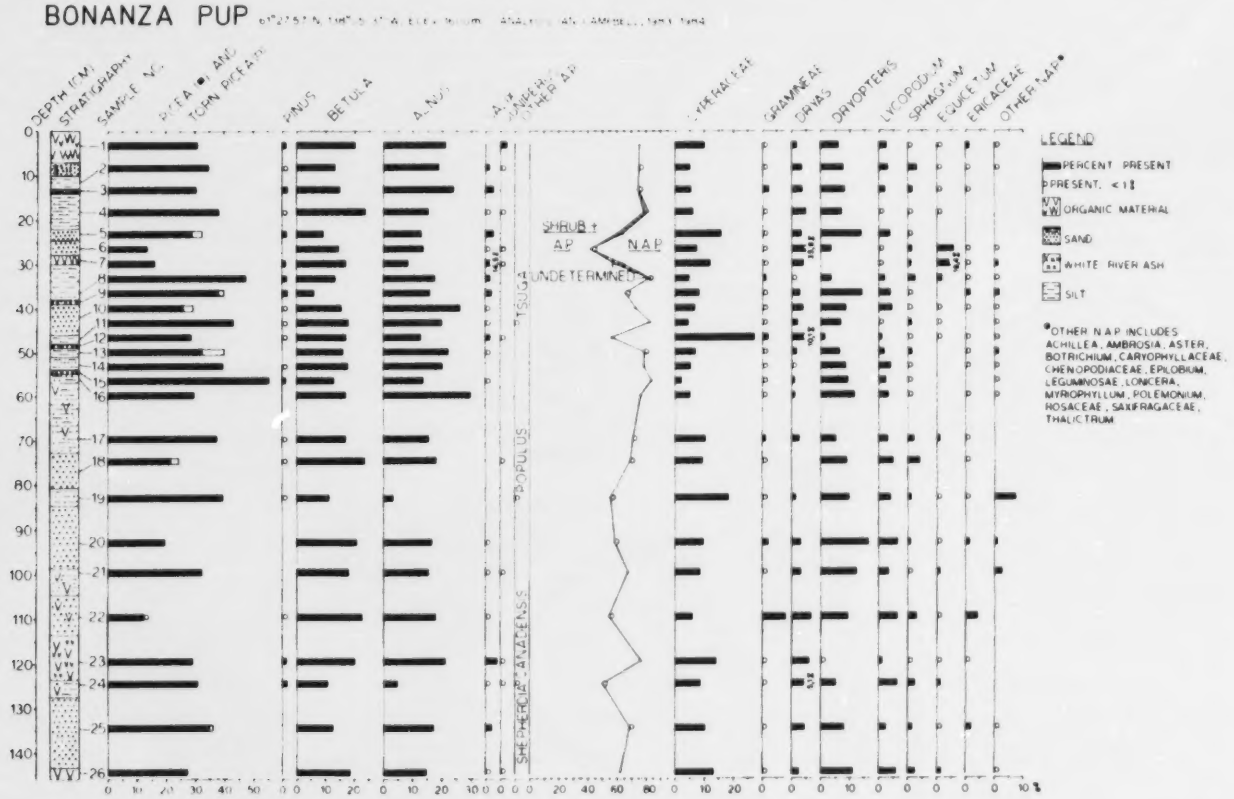


Figure 3. Bonanza Pup pollen diagram. The curves have an apparently high noise level, due to the changes in sediment type.

It may be argued that the spruce declines could represent forest fires, but in that case we would expect to see a parallel *Alnus* curve. Although the *Alnus* curve does follow the same rise-decline-rise pattern, it cannot be considered a perfect parallel. Correlation with other pollen diagrams in other areas would further argue against a forest-fire cause.

Bonanza Pup section

The varied sediment section is located near the head of Talbot Creek, along a small stream named Bonanza Pup by the field crew. A stratigraphic column accompanies the pollen diagram in figure 3.

This diagram is much more difficult to zone by eye, and although computer-zonation techniques have been attempted with this diagram, the results are far from satisfactory, often yielding several "zones" of one sample each. Replotting the data on a triangular graph with the three apexes representing regional, local, and ultra-local pollen types (Fig. 4), clearly shows two groupings of samples at each end of a linear cloud paralleling the regional-ultra-local axis. The group near the ultra-local apex is samples six and seven, while the group near the regional apex is samples 8–17. The remaining samples, one to five and 18–26, form two other groups, both scattered between the two extreme groupings. Thus the diagram can be divided on the basis of regional, local, and ultralocal pollen types into four zones: the first, samples 26–18, show dominance by neither ultra-local or regional types. The second, samples 17–8, is dominated by regional pollen types, with the exception of sample 12, which is slightly dominated by ultra-local types. This anomaly is accounted for in large part by a suspected *Dryas* stamen, which contributed 10% of the pollen in the sample. Samples seven and six are strongly ultralocally dominated; again stamens are a possibility, but even removing *Dryas*, *Salix* and *Equicetum* from the total leaves these samples at less than 22% *Picea* and ultralocally dominated. The remaining samples are again intermediate in composition.

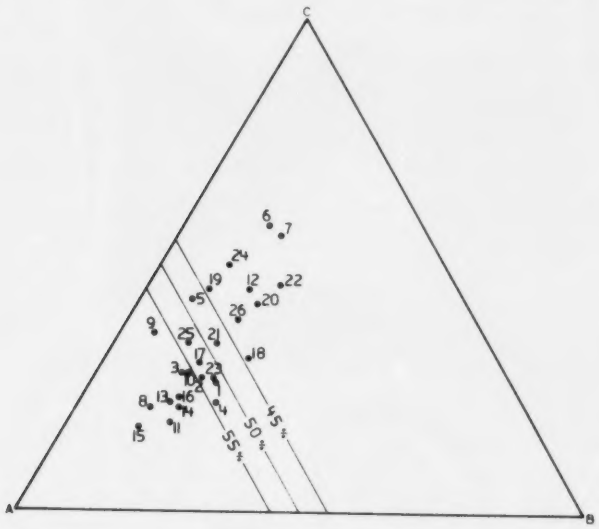


Figure 4. The samples from the Bonanza Pup diagram plotted by pollen provenance. The A apex represents 100% regional pollen (from more than 1 km from the site), apex B represents 100% local pollen (from sources within 1 km from the site), and apex C represents 100% ultralocal pollen (from sources within 100 m of the site). Samples 6 and 7 are clearly separated from the others, and so form one group. Samples 8–17 are clustered near the A apex, and form a second group. The remaining samples are moderate in composition, and form two groups, from 1–5 and 18–16.

These four zones can be correlated with those of the control section: the bottom zone has slightly lower *Picea* values than the next zone up, which in turn is followed by the lowest *Picea* values of the diagram, finally yielding to high values again at the top. That the *Picea* values at the top of the Bonanza Pup diagram do not reach the extreme attained by the same taxon in the ALRG diagram at this point, should not be considered a problem for the correlation, since the extreme height of the *Picea* peak in the ALRG diagram is largely a result of edaphic factors reducing the *Cyperaceae* and *Dryopteris* which had been dominant throughout the rest of the diagram.

The top three zones of both diagrams can be correlated with those found 75 km to the west in the Grizzly Creek area by Bourgeois and Geurts (1983), where the *Picea* curve followed the same pattern. Dating the ALRG section would be difficult, expensive, and probably unreliable, due to the very low organic content of the silt (generally below 5% loss on ignition). Dates in the Bonanza section are available; the volcanic ash has been dated at 1250 BP (Lerbekmo *et al.*, 1975), and sample 23 has been C-14 dated at 3840±60 BP (GSC-3752). Simple interpolation of dates between these two would obviously be highly misleading; however interpolations based on the rate of organic sedimentation only and using the soil-formation curve developed by Jacobson and Birks (1980), could be expected to provide somewhat more realistic dates. These interpolated dates will be tested in the near future by new C-14 datings on samples 9, 15, and 17.

The interpolated dates would place the zone boundaries at 2450, 1655, and 1380 BP respectively. These dates correspond startlingly well with those found by Bourgeois and Geurts (1983). They also correspond closely to the times of small "kicks" in the July mean temperature and mean annual precipitation curves of Heusser *et al.* (1985, p. 486) in the southern Alaska diagram (developed from pollen transfer functions).

Both of the cited papers agree that the period from 1380–1655 BP was warmer and drier than the present in that area; the same interpretation can be extended to that period in the Ruby Range based on the Bonanza Pup and ALRG diagrams. Given the similarity between the period from 1380–1655 BP and that from 2450 BP to the bottoms of the diagrams, the same interpretation can again be placed on that period in the Ruby Range; this corresponds again with the southern Alaska diagram in Heusser *et al.* (1985). The other two periods, from the present to 1380 BP and from 1655 to 2450 BP, are interpreted as having a climate similar to today's. More detailed explanations of these paleoclimatic interpretations will not be given here, as they are not the purpose of this paper.

Pollen-sediment relationships in the Bonanza Pup section

Figure 5 shows the absolute pollen content (grains of pollen per gramme of dried sediment) of the Bonanza Pup section.

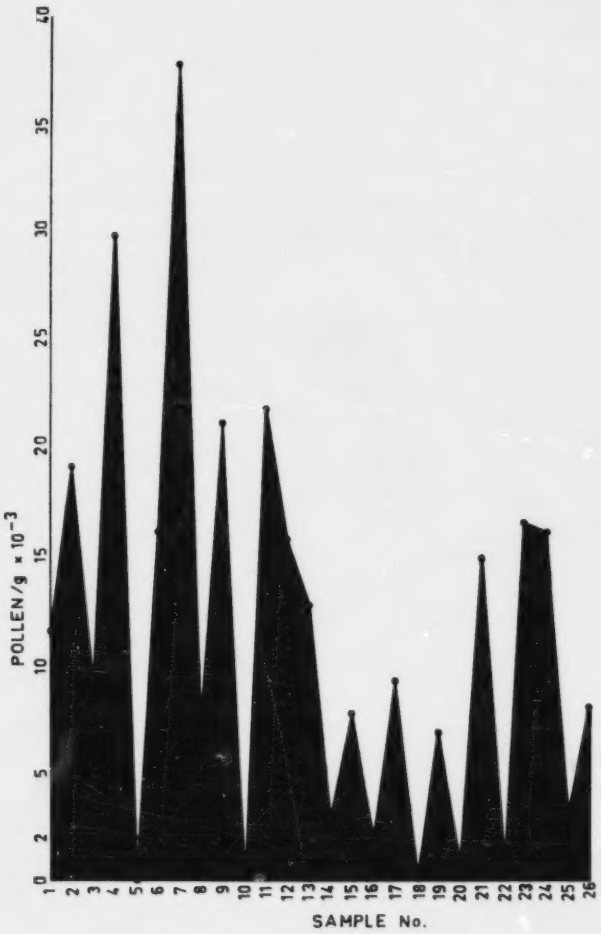


Figure 5. Pollen/gramme of dried sediment, Bonanza Pup section. The strong difference in pollen content is a function of sediment type.

The apparently random pattern is due to the different sediment types; figure 6 shows the relationship between sediment types and absolute pollen content. It is quite clear that more organic sediments tend to have higher pollen contents. The reason for this distribution of pollen types is relatively simple: the total sedimentation rate is the sum of the organic sedimentation rate and the mineral sedimentation rate. The organic sedimentation rate is essentially fixed at a very low level by the unfavourable climatic conditions prevalent in the area, so the total sedimentation rate tends to vary primarily with the rate of mineral deposition. A high rate of mineral deposition will therefore result in both a low organic content and a high sedimentation rate, which in turn results in a low pollen content.

Figure 7 shows the distributionof sediment types on the same triangular plot which was used to zone the diagram. Although the silts do show a slight tendency to cluster near the regional apex and sands nearer the ultralocal apex, peats are randomly distributed. The reason for this distribution is also self-evident: the silts are a subaqueous deposit, mostly the result of temporary ponding. Therefore the only possible ultralocal

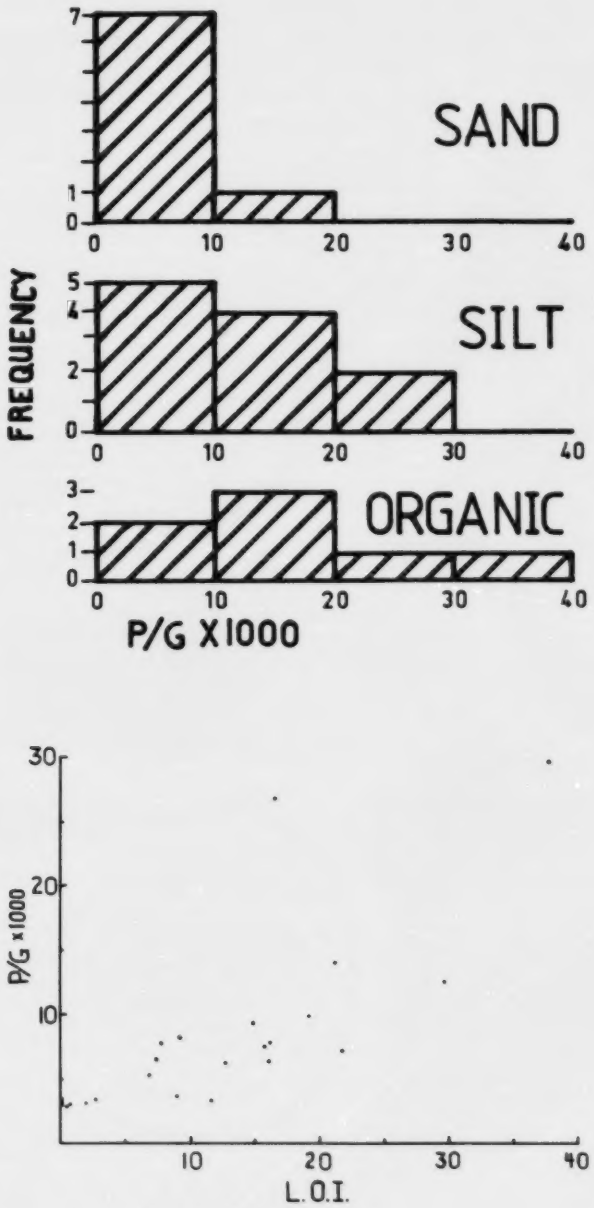


Figure 6. A. Histogram relating pollen content to sediment type.

B. Pollen content is largely a function of percentage organic content.

taxa would be aquatics. Although many "wet" taxa occur in the area, including sedges and *Equicetum*, they are unable to establish themselves in such an ephemeral environment. Therefore the only pollen which may settle in the pond and in the silts is local and regional in origin. The sands however are deposited by the stream of Bonanza Pup wandering from channel to channel. Since the stream may settle in a given channel for several successive seasons, it promotes the growth of ultralocal taxa along its banks. This is clearly seen in the frequent dense growths of willows often found along well-established streambeds. Furthermore, the sands are

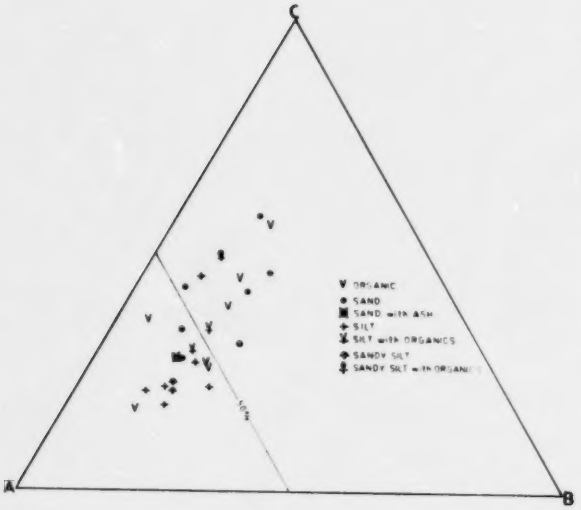


Figure 7. Distribution of the different sediment types present in the Bonanza Pup diagram, plotted on the same triangular graph used in Fig. 4. Although the silts tend be grouped near the Regional apex (A) and sands near the Ultralocal apex (C), the pollen zones involve several sediment types, and so are not themselves a product of distortion of the pollen spectra by the sediment types.

deposited by higher energy level waters, which are more likely to carry pollen washed down from the surrounding slopes. For these reasons, the sands will tend to have a high concentration of ultralocal taxa. The peats will develop in a wider variety of conditions than either the sands or silts, and can therefore be expected to show a wider variety of pollen spectra.

This leaves the question of the validity of the zones established for the Bonanza section; it must be demonstrated that they are not an artefact of the changing sediment type. The zone formed by samples six and seven, the shortest and therefore most dubious zone, is composed of one layer of sand, and one layer of peat. The other zone of extreme composition, the zone formed by samples 8–17, includes sand, silt, and peat. Both of the intermediate zones also show all three sediment types. This distribution allows us to conclude that the distortions of the pollen spectra which are due to the sediment variations are not sufficient to prevent the detection of paleoclimatic signals.

Conclusions

The paleoclimatic interpretations presented here are not the primary thrust of this paper. They will be dealt with more thoroughly elsewhere. For now it will suffice to note that they confirm and extend northeastwards the results of Heusser *et al.* (1985), and those of Bourgeois and Geurts (1983).

These results must still be considered preliminary, until further pollen diagrams of sedimentologically variable deposits have been studied. However, they are encouraging, and suggest that, with proper care, such deposits may add valuable information to the pollen record of alpine regions where the preferred thick accumulations of peat and gyttja are often nearly or totally absent.

Acknowledgments

This research was funded in part by a Natural Sciences and Engineering Research Council grant (NSERC A6888), by a grant from the Royal Canadian Geographical Society, and by Northern Research grants.

The author would like to express his thanks to Peter Johnson of the University of Ottawa for welcoming him in his field camps, Dr. Wes Blake of the Geological Survey for the C-14 date, and particularly Dr. Marie-Anne Geurts, who supervised all aspects of the research.

References

Bourgeois, J.C. and Geurts, M.-A. 1983. Palynologie et morphogenèse récente dans le bassin du Grizzly Creek (Territoire du Yukon). Canadian Journal of Earth Sciences 20(10):1543–1553.

Gray, J. 1965. Extraction techniques: In: Kummel, B. and Raup, D., eds. Handbook of paleontological techniques. San Francisco, W.H. Freeman and Co. 530–587.

Heusser, C.J., Heusser, L.E., and Peteet, D.M. 1985. Late-Quaternary climatic change on the American North Pacific Coast. Nature 315(6):485-487.

Jacobson, G.L. Jr., and Birks, H.J.B. 1980. Soil development on Recent end-moraines of the Klutlan Glacier, Yukon Territory, Canada. Quaternary Research 14:87–100.

Lerbekmo, J.F., Westgate, J.A., Smith, D.G.W., and Denton, G.H. 1975. New data on the character and history of the White River volcanic eruption, Alaska. In: Suggate, R.P., and Cresswell, M.M. eds. Quaternary Studies. Wellington: The Royal Society of New Zealand. 203–209.

PÉTROGRAPHIE DES SÉDIMENTS, OUTIL DE RECONSTRUCTION D'ÉCOULEMENTS GLACIAIRES AU S.O. DU YUKON

Véronique Dewez

Département de Géographie, Université d'Ottawa, Ottawa, Ontario K1N 6N5

Niveau: Doctorat

Résumé

L'origine et l'extension des langues de glace wisconsiniennes font partie de l'étude paléogéographique entreprise dans la région située entre les lacs Kluane et Aishihik, au S.O. du Yukon. Les dépôts les plus puissants ainsi que les sites-clés ont été échantillonnés, notamment pour l'analyse en lames minces des matériaux de 0,5 à 2 cm. La pétrographie d'une centaine d'échantillons permet de déterminer, en comparaison avec les cartes géologiques, si les dépôts correspondent à une glace d'origine locale/régionale

ou au contraire extra-régionale. En effet, les échantillons prélevés le long du lac Kluane, ainsi que ceux récoltés dans les vallées de Sekulmun et Aishihik comportent des débris extra-régionaux, provenant de la chaîne des St Elias, notamment grauwackes et greenstones, tandis que les échantillons provenant du coeur de la chaîne Ruby, entre les lacs Kluane et Sekulmun, ne comportent que des débris locaux ou strictement régionaux, granodiorites et schistes. Ceci confirme l'interprétation de deux grandes langues de glace ayant envahi les vallées occupées actuellement par les lacs Kluane, Sekulmun et Aishihik à partir des Monts St Elias, mais démontre surtout qu'elles ne se sont pas rejointes au coeur de la chaîne Ruby. Leur extension latérale dans les vallées de cette chaîne est délimitée par la présence ou non de débris extra-régionaux dans les dépôts glaciaires échantillonnés. A l'intérieur même de la chaîne et dans le bassin d'Aishihik, des différences pétrographiques entre échantillons indiquent les provenances de certaines langues.

Mots-clés: S.O. Yukon, écoulement glaciaire, Wisconsin, pétrographie de sédiments, lames minces.

Abstract

The origin and extension of Wisconsinan ice-tongues were included in the palaeogeographical study carried out in the region lying between Kluane and Aishihik Lakes, in southwestern Yukon. The largest deposits and the key-sites were sampled, especially for the purpose of analyzing thin sections of material from 0.5 to 2 cm. From the petrography of about a hundred samples it is possible to determine, with the aid of the geological maps, whether the deposits are attributable to ice originating locally or regionally or outside the region. Samples collected along the shore of Kluane Lake, and also those from the Sekulmun and Aishihik valleys, contain extra-regional debris originating in the St. Elias Range, notably "grauwackes" and "greenstones", while the samples from the interior of the Ruby Range, between Kluane and Sekulmun Lakes, contain only debris which is local or strictly regional, granodiorites and schists. These findings confirm the interpretation according to which two large ice tongues originating in the St. Elias Range invaded the valleys now occupied by Kluane, Sekulman and Aishihik Lakes, but they also show that they did not meet again in the interior of the Ruby Range. Their lateral extension into the valleys of this range is delimited by the presence, or absence, of extra-regional debris in the sampled glacial till. Within the interior of the range and in the Aishihik watershed petrographic differences between samples indicate the origins of some tongues.

Key words: Yukon; glacial flow; Wisconsin; sediment petrography; thin sections.

Introduction

Depuis le début du siècle, le S.O. du Yukon a fait l'objet de nombreuses études portant sur les problèmes d'extensions glaciaires et origine des glaces au Pléistocène. Pourtant même la reconstruction de la glaciation la plus récente (Wisconsinien supérieur) demeure incomplète, puisque dans sa récente cartographie, Prest (1984) laisse indéterminés les raccords entre les lacs Kluane et Sekulmun (fig. 1). Ce secteur-clé a donc été choisi comme région d'étude (fig. 2), avec pour but d'y préciser l'extension des langues glaciaires principales ainsi que l'origine (locale, régionale ou extra-régionale) des glaces par l'analyse pétrographique en lame mince des sédiments correspondants.

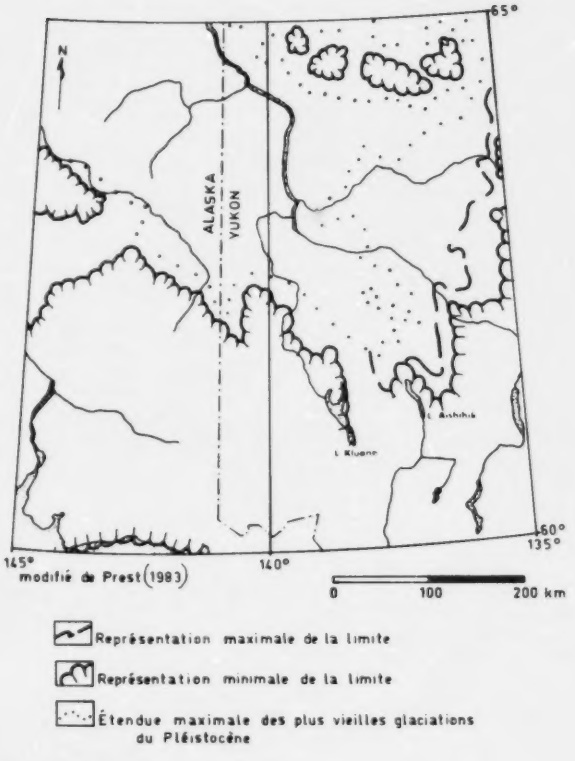


Figure 1. Le complexe glaciaire du Wisconsin.

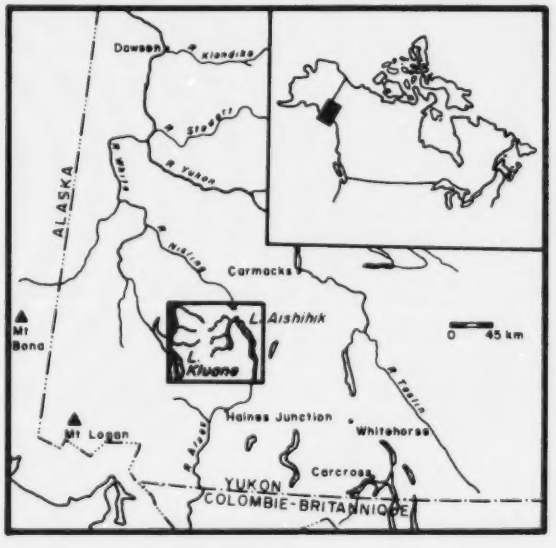


Figure 2. Carte de localisation.

Cadre physique

Au niveau physiographique, la nomenclature encore actuellement utilisée pour l'ensemble de la cordillère canadienne

est celle de Bostock, qui date de 1948. Notre région d'étude (fig. 3) correspond au plateau de Kluane, subdivisé en deux chaînes allongées, dénommées Ruby et Nisling, et un bassin, celui d'Aishihik. Au sud, ce plateau correspond à la chaîne de Dezadeash, qui est coupée de la chaîne Ruby par la large vallée O-E de Takhini. À l'ouest du lac Kluane se dressent les Monts St Elias, séparés du plateau de Kluane par la faille Shakwak. Son prolongement vers le S.O. délimite les chaînes Boundary, qui font partie des Montagnes côtières.

Le plateau de Kluane (altitude = 1600m) apparaît comme une ancienne surface d'érosion profondément découpée par des vallées à versants très raides, avec des dénivellations dépassant 600m. Les chaînes Ruby, Nisling et Dezadeash y forment des rides plus montagneuses, tandis que le bassin d'Aishihik consiste en une large dépression légèrement vallonnée (altitude ≃ 1200m). Certains des plus hauts pics d'Amérique du Nord se trouvent dans les Monts St Elias, qui de ce fait contrastent fortement avec le plateau de Kluane. Cette région comporte actuellement des champs de glace très étendus, de même que celle des Montagnes côtières.

Ce cadre physiographique joue un rôle important dans notre étude, puisqu'il influence la localisation des sources possibles de glace et surtout les directions d'écoulement de cette glace selon l'axe des grandes vallées qui découpent le plateau de Kluane.

Géologie

La géologie de la région étudiée et environnante a été levée en trois temps, par trois géologues différents. La carte de Kluane date de 1967 et fut levée par Muller, tandis que Tempelman-Kluit a levé la carte d'Aishihik de 1971 à 1973. Quant à celle de Dezadeash, juste au sud de la carte d'Aishihik, Kindle en a fait le levé de 1946 à 1950. La juxtaposition des cartes pose donc inévitablement des problèmes, car non seulement les légendes des cartes diffèrent, mais de plus les limites spatiales d'unités comparables ne se prolongent pas d'une carte à l'autre. De manière générale, on peut dire que la faille de Shakwak sépare les formations des Monts St Elias de celles du plateau de Kluane et de la chaîne Boundary. Les Monts St Elias consistent en effet, dans les secteurs de Kluane et Dezadeash, en un assemblage eugéosynclinal de roches essentiellement sédimentaires, mais également volcaniques et intrusives. Malgré leur rareté, les fossiles ont permis d'échelonner l'âge des différentes formations depuis le Dévonien jusqu'au début du Tertiaire. Le plateau du Yukon, ainsi que les chaînes Boundary dans la région de Dezadeash, correspondent plutôt à des roches granitiques et métamorphiques. Les roches sédimentaires qui

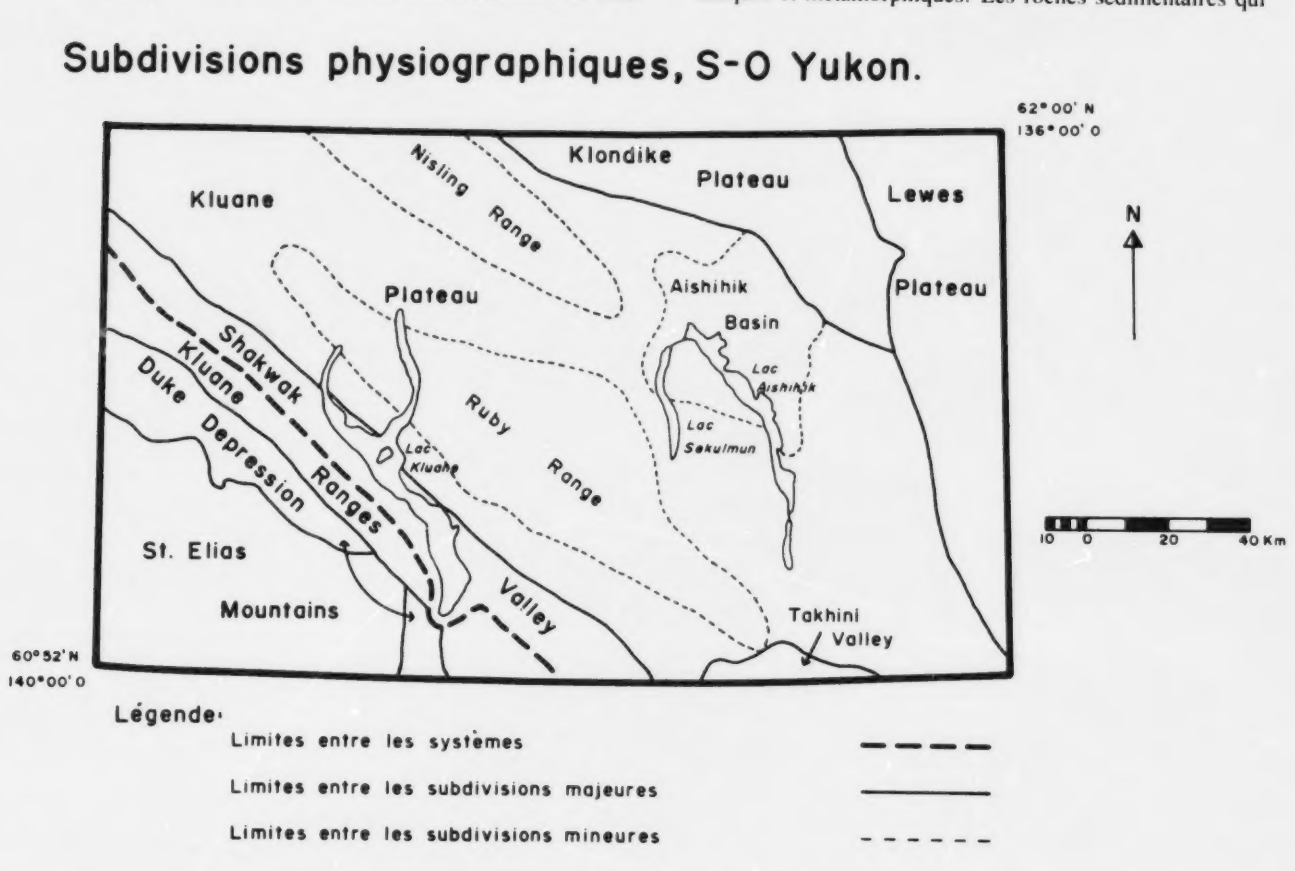


Figure 3. Carte physiographique.

affleurent présentent un degré moyen de métamorphisme, et n'ont livré aucun fossile. Leur datation approximative va du Précambrien au début du Tertiaire.

Ces grandes unités se retrouvent dans la carte de Douglas (1980), dressée au 1:1000000. L'accent y est mis sur la lithologie, ce qui est du plus grand intérêt pour nous puisque nous analysons dans cette étude la pétrographie de sédiments glaciaires et paraglaciaires, et l'âge relatif des grains ne joue aucunement dans nos interprétations. La figure 4 synthétise les lithologies fondamentales de la région environnante. Comme mentionné ci-dessus, les Monts St Elias se distinguent aisément par l'importance des roches sédimentaires (grauwacke, argillite, calcaire) interstratifiées avec des roches volcaniques basaltiques et andésitiques ainsi que des «greenstones». La chaîne Boundary consiste en une vaste intrusion granitique, tandis que le plateau de Kluane montre une alternance de roches métamorphiques (schistes) et de la famille des granites (granodiorites, monzonites et alaskite), avec au nord une formation de dykes (porphyres à feldspath) et à l'est du lac Aishihik des affleurements de tuf. Enfin, les quelques pointements de calcaire cristallin et marbre se concentrent au S.E. du lac Aishihik, de part et d'autre du lac Sekulmun et au nord du lac Kluane.

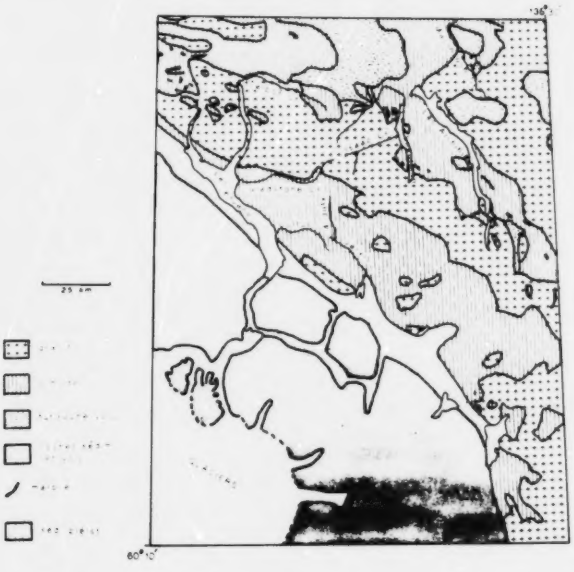


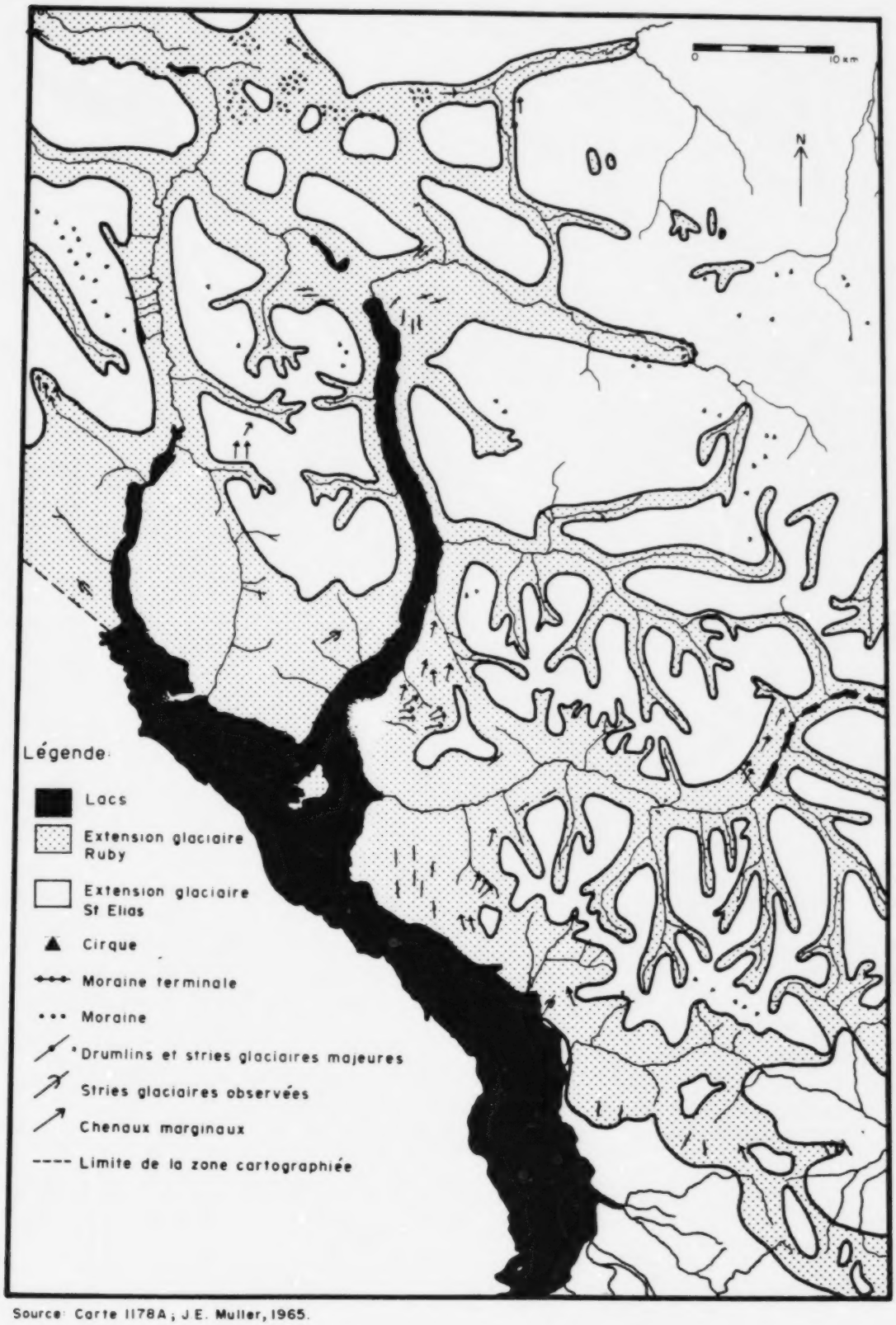
Figure 4. Carte lithologique généralisée du S.O. Yukon.

Glaciation du Wisconsinien supérieur

En un demi siècle, divers rapports traitant des glaciations dans la région à l'étude ont été publiés à la Commission géologique du Canada. Il s'agit principalement de Bostock (1948, 1966), Kindle (1953), Hughes (1967, 1968), Muller (1967) ainsi que Hughes *et al.* (1969). Tous s'accordent sur la succession de deux épisodes glaciaires distincts, appelés Nisling et Ruby par Muller, mais Reid et McConnell par Bostock et Hughes. Seul le dernier épisode est relativement bien délimité dans le temps, avec un maximum se situant vers 13500 BP, donc au wisconsinien supérieur. Nous l'appellerons McConnell, suivant la nomenclature du rapport de synthèse de Hughes *et al.* (1969). Les glaces qui ont couvert la région à cette époque font partie de la calotte glaciaire St Elias, et proviennent des Monts St Elias ainsi que des «Montagnes côtières». À cette glace s'ajoute celle de petits glaciers locaux, dont l'importance n'est past précisée (Hughes *et al.*, 1969). La figure 5 montre que les glaces ont envahi la région suivant deux lobes distincts s'écoulant principalement vers le N.O. À l'ouest, la dépression correspondant à la faille de Shakwak (partiellement occupée actuellement par le lac Kluane) a permis une concentration importante de glaces, et la formation d'un lobe qui s'est écoulée bien au N.O. de notre région. Ce lobe, que nous appellerons 'lobe de Kluane', a débordé vers l'est dans la chaîne Ruby suivant l'axe O-E de grandes vallées telles celles des rivières Gladstone (A), Raft (B) et Talbot (C) (fig. 5). À l'est, un lobe d'une cinquantaine de km de large s'est écoulé vers le bassin d'Aishihik. Les glaces se sont faufilées d'une part dans les vallées d'Aishihik, West Aishihik (D) et Sekulmun; elles proviennent d'autre part du débordement de la langue qui s'écoulait dans le ruisseau Jarvis (E) via quelques cols peu élevés. Ce lobe, que nous appellerons 'lobe d'Aishihik', a débordé vers l'ouest dans la chaîne Ruby, notamment à la faveur des vallées des rivières Isaac (F) et Albert (G). La figure 5 montre également que les deux lobes formaient une seule masse de glace dans la région de Dezadeash. Kindle (1953) mentionne à ce propos que la vallée de la rivière Takhini a servi de principal collecteur de glace.

Figure 5. Carte glaciaire du S.O. Yukon.

Si l'on rentre davantage dans les détails, on constate cependant des divergences d'interprétation et des lacunes dans les délimitations. Pour Muller (1967), qui a cartographié le secteur de Kluane (fig. 6), pratiquement toutes les vallées de la chaîne Ruby sont envahies par un système de langues glaciaires en provenance du lobe de Kluane, alimentées le long du trajet par des glaciers locaux. Pour Hughes



Source: Carte 1178A; J.E. Muller, 1965.

Figure 6. Carte glaciaire du secteur de Kluane.

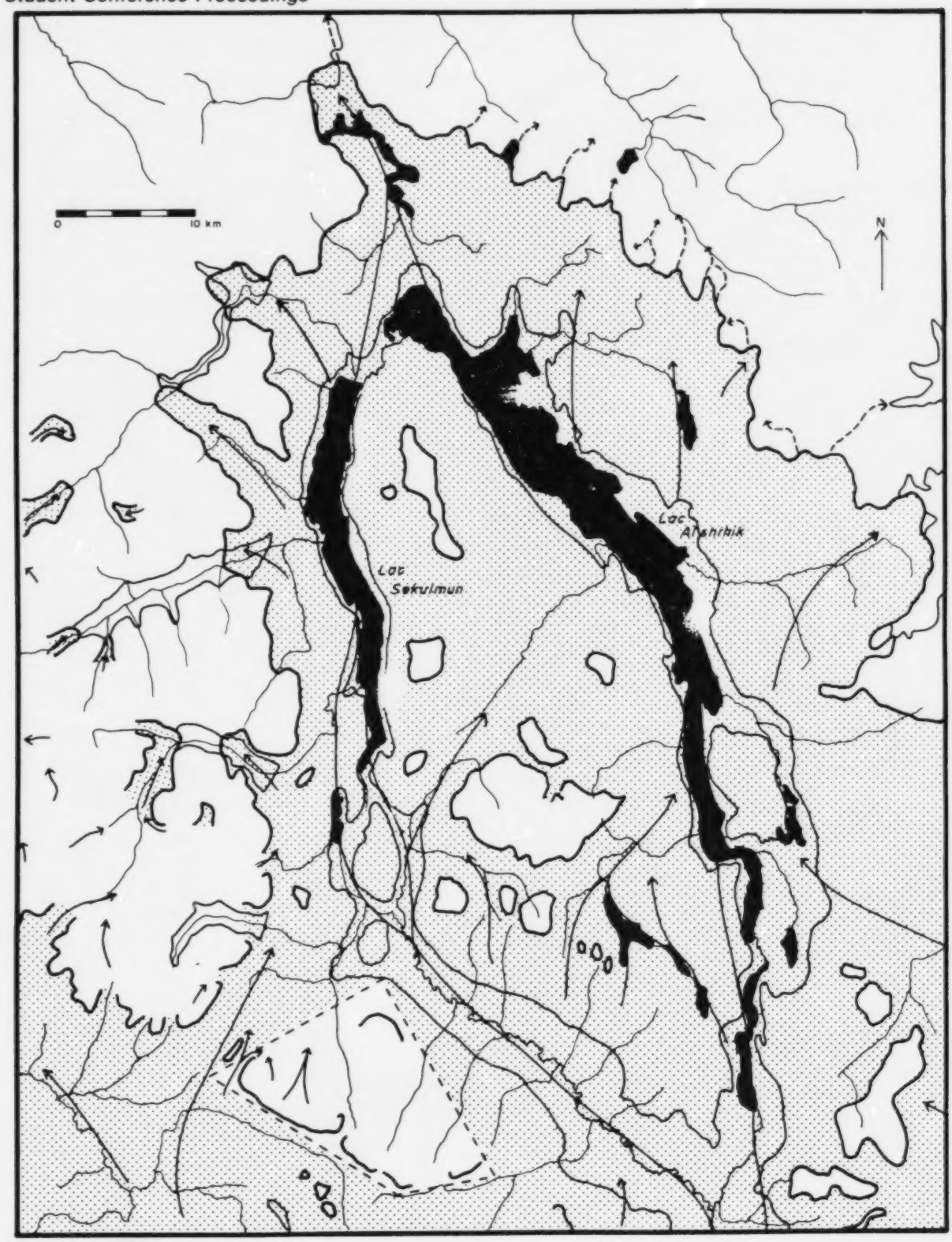


Figure 7. Carte glaciaire du secteur d'Aishihik.

et al. (1969) (fig. 5), les limites dans ces vallées sont légèrement plus restrictives que celles de Muller, avec quelques petits glaciers indépendants. Dans le secteur d'Aishihik, la topographie est plus plane, et les altitudes plus faibles, ce qui rend plus continue la zone recouverte par les glaces. Seuls quelques nunataks émergent. Le débordement du lobe vers l'ouest du lac Sekulmun dans les vallées transversales reste non délimité. La récente interprétation de Hughes (manuscrit) pour la carte d'Aishihik (fig. 7) respecte les grands traits de l'interprétation de 1969, mais délimite mieux la pénétration de la langue glaciaire dans les vallées adjacentes. Davantage de nunataks apparaissent. Plusieurs limites sont non cartographiées car l'auteur ne connaît pas l'importance des glaciers locaux.

Étant donné l'importance (nombre et volume) des dépôts laissés par la Glaciation de McConnell dans le secteur (moraines, kames terrasses, deltas, eskers. . .), nous avons tenté d'utiliser la pétrographie de ces dépôts sédimentaires pour améliorer la connaissance des sources et extensions des lobes de Kluane et Aishihik par rapport à celles des glaciers locaux.

Pétrographie des sables grossiers et des graviers

Méthode

Les dépôts les plus puissants ainsi que les sites-clés ont été échantillonnés au cours de trois étés. Seuls les sédiments possédant une fraction grossière (>2mm) suffisante étaient susceptibles de fournir des grains propres à leur identification pétrographique; nous en avons sélectionné 92, localisés à la figure 8. Pour ces échantillons, nous avons choisi les grains les plus gros (0,5 à 2 cm) de chaque catégorie identifiée à la loupe binoculaire. Les comptages sont donc qualitatifs (présence ou absence de chaque type de roche) et non quantitatifs (quatre grains de granodiorite sur un total de huit grains pour un échantillon ne veut pas dire que celui-ci soit composé à 50% de granite). Afin d'obtenir des lames minces (30μ) donnant la plus grande surface plate des grains, ceux-ci ont dû subir plusieurs opérations: 1) montage temporaire, 2) sciage à mi-épaisseur des grains et polissage de cette surface, 3) montage définitif sur cette surface, 4) destruction de la première lame de montage et réduction à l'épaisseur de 30μ et 5) montage du couvre-objet protecteur. Les lames sont alors prêtes à l'analyse.

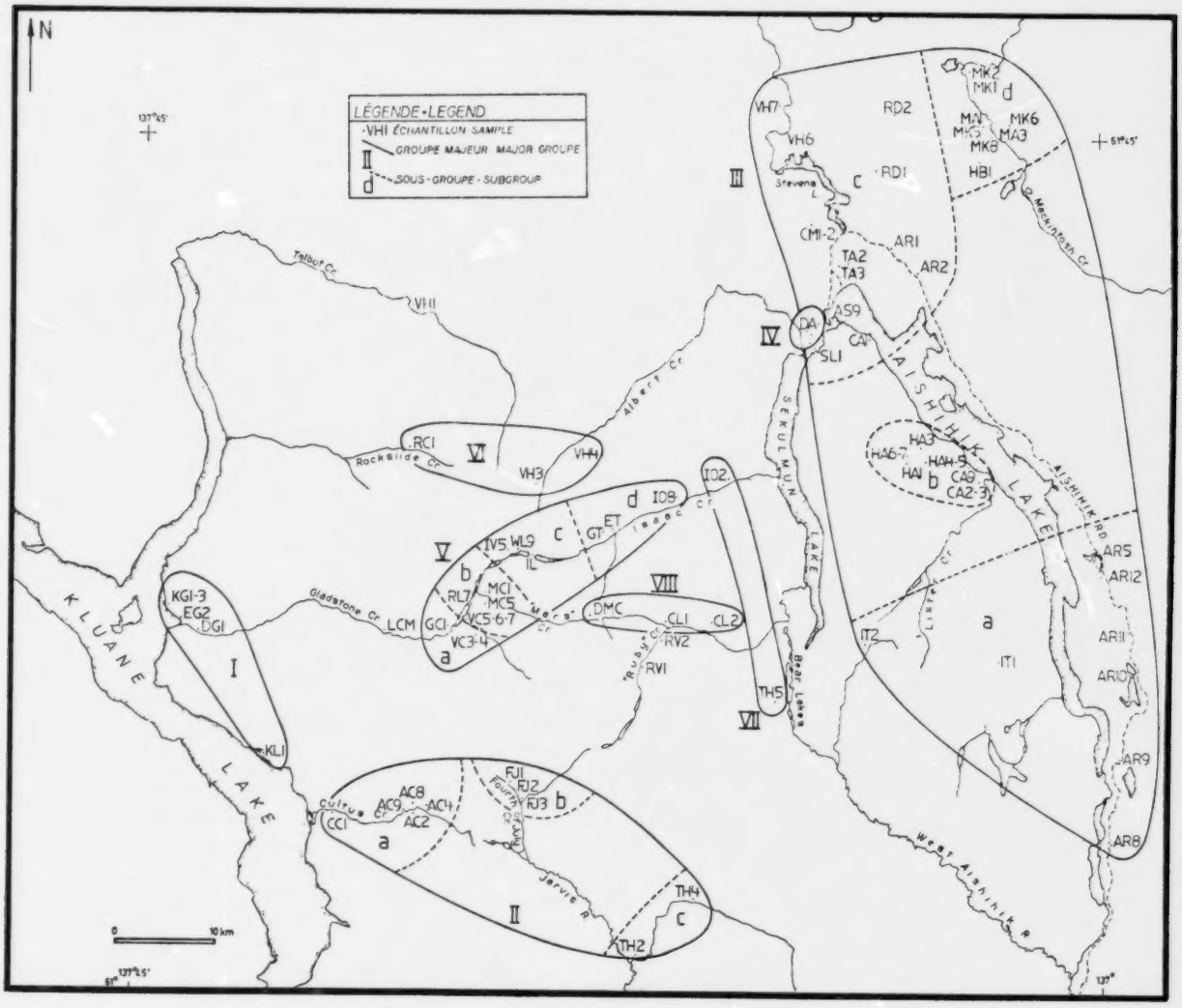


Figure 8. Localisation des sites d'échantillonnage.

Étant donné la petite superficie des grains, l'identification complète du type de roche est souvent hasardeux, voire impossible dans certains cas. Nous avons donc opté pour une subdivision en grandes catégories: roches sédimentaires (détritiques et carbonates), roches plutoniques (de type granitique ou gabbroïque), roches volcaniques (tufs et 'flow rocks') et métamorphiques (schistes, quartzites, amphibolites). Nos interprétations ont été partiellement guidées par les photographies en couleurs et les explications fournies par Mackenzie and Guilford (1980), Mackenzie *et al.* (1982) et Adams *et al.* (1984). Les analyses ont été effectuées à l'aide d'une loupe binoculaire Wild M8, équipée d'occulaires 20X, d'un set complet de polarisation, et dont le zoom permet des grossissements variant de 12 à 100.

Dans les roches sédimentaires, les grauwackes se reconnaissent facilement par la présence de fragments de roches hétérométriques, de nature hétérogène, à arrondi variable, noyés dans une matrice fine (fig. 9). Les carbonates se distinguent à l'oeil nu par leur réaction à l'acide chlorhydrique, et au microscope par leur très haute teinte de biréfringence en lumière polarisée à nichols croisés. Il est à noter ici que nous n'avons pu distinguer les calcaires des marbres, vu la petite taille des grains analysés. Les autres roches sédimentaires se caractérisent par l'allure en couches planes des constituants, dont la taille varie de quelques microns (argillites) à quelques dizaines de microns (grès); nous les avons regroupés sous le terme 'sédiments à grain fin'. Les roches plutoniques se caractérisent par la juxtaposition parfaite (comme les pièces d'un casse-tête) de cristaux bien développés, qui ne montrent aucune orientation préférentielle. Nous avons reconnu des granodiorites, des granodiorites à hornblendes, et des roches plutoniques basiques, de type gabbroïque. En lames minces, les granodiorites apparaissent incolores en lumière polarisée plane, car constitués de quartz et feldspath, seules les hornblendes y apparaissent vertes (fig. 10) et sont pléochroïques. Sous les nichols croisés par contre, les éléments constituants ainsi que la texture typique se distinguent aisément (fig. 11). Les roches gabbroïques se caractérisent par l'absence de quartz, mais l'abondance de plagioclases et minéraux mafiques (amphiboles, pyroxènes ou péridots). La figure 12 illustre deux gabbros constitués de plagioclases et d'amphiboles. Les roches métamorphiques présentent la variété la plus grande, mais tous possèdent un élément commun: des traces de foliation. Les quartzites se reconnaissent aisément sous les nichols croisés par l'orientation préférentielle des cristaux de quartz en bandes parallèles (fig. 13); les amphibolites par l'absence de quartz et l'alternance de bandes de plagioclases et d'amphiboles (fig. 14); et les schistes par la présence de quartz et plagioclases, avec des micas et minéraux opaques soulignant une foliation parfois extrêmement chiffonnée (fig. 15). Les roches volcaniques se subdivisent en deux types: les tufs, caractérisés par des porphyres de verre, quartz et/ou plagioclases cimentés dans une matrice microcristalline (fig. 16), et des 'flow rocks' constitués de grains fins montrant des textures d'écoulement. La plupart des 'flow rocks' identifiés sont de type basaltique, comme celui de la figure 17.

L'ensemble de ces photographies, prises à l'aide d'un réflex Nikon monté sur microscope optiphot Nikon, montrent clairement que les caractères essentiels des roches sont conservés dans les grains analysés, malgré la petite taille de ceux-ci, permettant leur interprétation pétrographique avec un degré de fiabilité suffisant.

Analyse des résultats

Les relations pétrographie/échantillons sont synthétisées au tableau I, dans lequel nous avons regroupé les échantillons suivant leur secteur de localisation (chacun des groupes étant représenté sur la figure 8). Ceci permet de mieux visualiser les grandes tendances, tout en conservant le détail nécessaire. On constate tout d'abord que les trois premiers groupes, à savoir les secteurs de Kluane, Jarvis Cultus ainsi que toute la vallée d'Aishihik Sekulmun présentent une diversité remarquable (jusqu'à 10 pétrographies différentes), alors que dans ceux situés au coeur de la chaîne Ruby la pétrographie se limite le plus souvent à trois variétées, dont une par groupe nettement dominante. Ceci rappelle évidemment l'interprétation donnée précédemment de deux grands lobes de glace s'écoulant l'un dans la dépression centrée sur la faille Shakwak et l'autre dans les vallées des rivières Sekulmun-Aishihik, par opposition à des glaciers locaux dans le secteur central de la chaîne Ruby. L'examen détaillé du tableau I permet de confirmer et raffiner cette hypothèse. En effet, on peut voir que les grains provenant de roches sédimentaires (grauwackes, sédiments à grain fin) apparaissent systématiquement dans les trois premiers secteurs, qu'ils sont absents dans les vallées intérieures de la chaîne Ruby, et se retrouvent dans les échantillons LCM et RV1. Or, la carte lithologique (fig. 4) montre que ces roches sédimentaires caractérisent les formations des St Elias, où elles se rencontrent en abondance, alors qu'elles sont totalement absentes dans le plateau de Kluane. Les sédiments homométriques à grain très fin (quelques μ) présentant souvent des difficultés d'interprétation à la loupe binoculaire, ce sont les grauwackes, dont les caractéristiques sont typiques (fig. 9), que nous considérerons comme la roche-clé. Sa présence dans un échantillon indique en effet à coup sûr que la source est la chaîne des St Elias, donc extra-régionale. Son absence dans un échantillon est en revanche plus délicate à interpréter, car les grains de grauwacke ne sont jamais dominants, et pourraient être présents dans le dépôt, mais absent de l'échantillon récolté. Cependant, leur absence systématique dans une série d'échantillons provenant d'un même secteur peut être considérée comme nettement plus significative. C'est une raison supplémentaire pour laquelle nous avons regroupé ceux-ci au maximum, tout en veillant à maintenir isolés les échantillons particuliers.

Les dépôts échantillonnés en bordure du lac Kluane (groupe I) se caractérisent par la présence de roches sédimentaires, de calcaires cristallins (ou marbres), de roches gabbroïques, volcaniques et métamorphiques, mais la quasi-absence de granodiorites. Les roches sédimentaires indiquent, nous l'avons vu, les St Elias comme source; les calcaires cristallins ainsi que les roches volcaniques et gabbroïques renforcent encore cette source, puisque les deux premiers types se rencontrent dans la plupart des unités et que les intrusions basiques et ultrabasiques font partie intégrante du groupe Cache Creek tel que décrit par Muller (1967). L'abondance relative des gabbros peut s'expliquer aisément par le fait que le Groupe de Cache Creek forme la partie frontale de la chaîne de Kluane, et fait donc directement face à la dépression de Shakwak. Les roches métamorphiques enfin

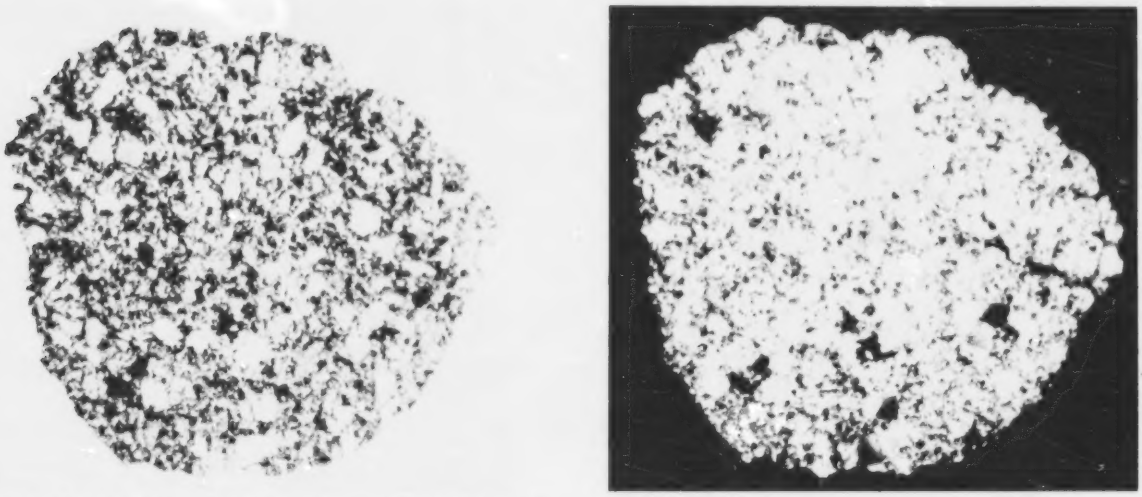


Figure 9 Photographie d'un grain de grauwacke a) LLP b) XLP.

NB: LLP = lumière polarisée plane et XLP = lumière polarisée avec nichols croisés.
L'aggrandissement des photographies est de 12X.

Figure 10. Photographie d'un grain de granodiorite à hornblende (LLP).

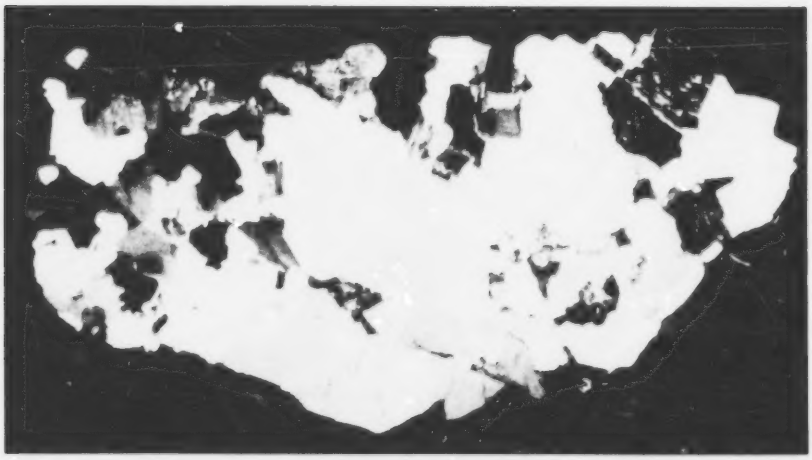


Figure 11. Photographie d'un grain de granodiorite (XLP).

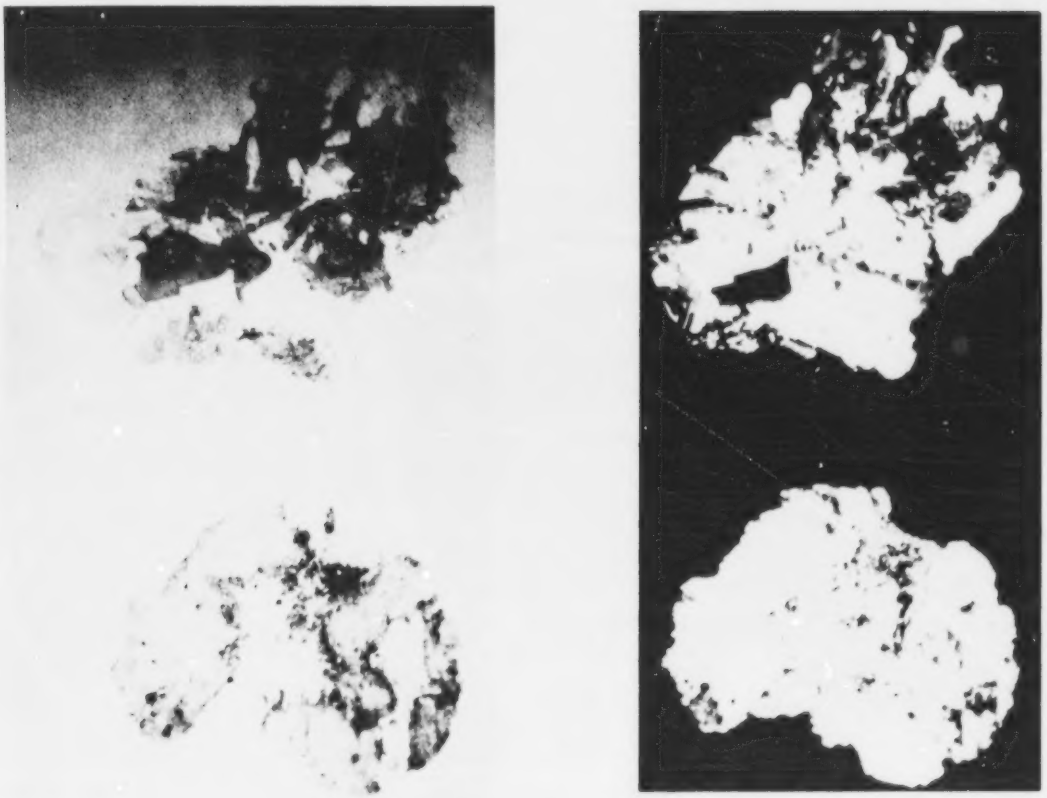


Figure 12. Photographie de 2 grains de gabbro a) LLP b) XLP.

Figure 13. Photographie d'un grain de quartzite (XLP).

Figure 14. Photographie d'un grain d'amphibolite (LLP).

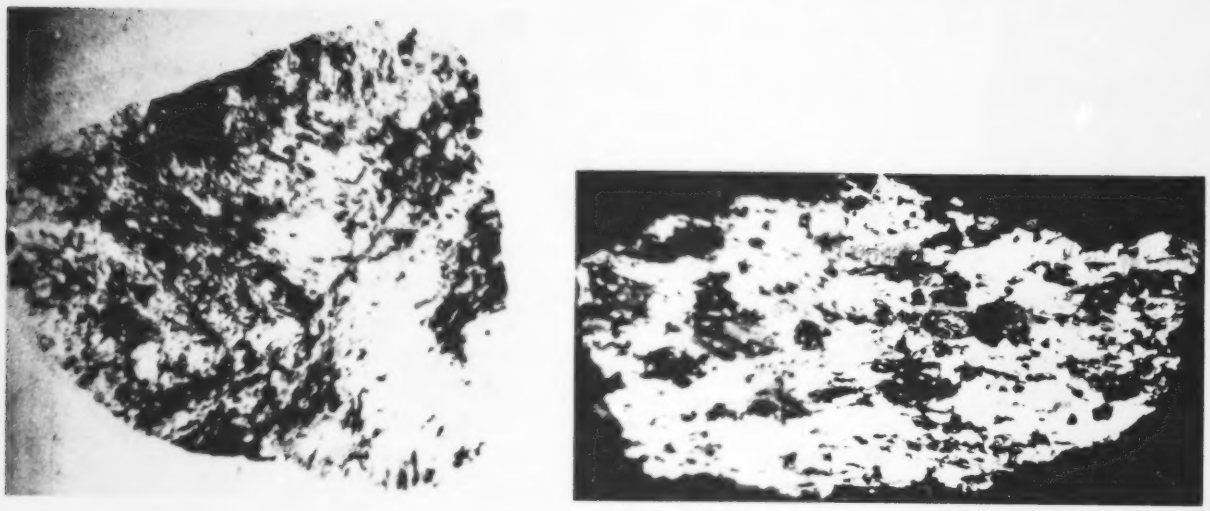


Figure 15. Photographie de grains de schiste a) LLP b) XLP.

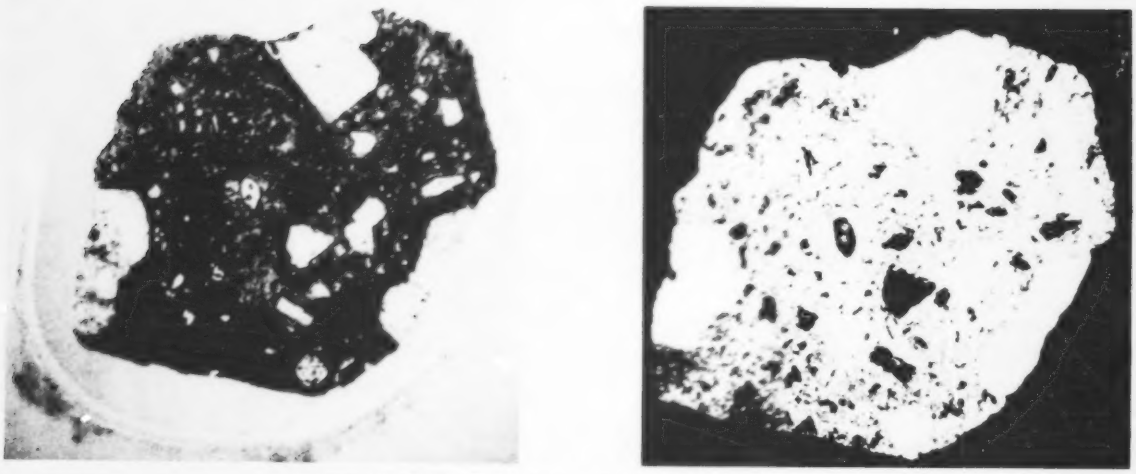


Figure 16. Photographie d'un grain de tuf a) LLP b) XLP.

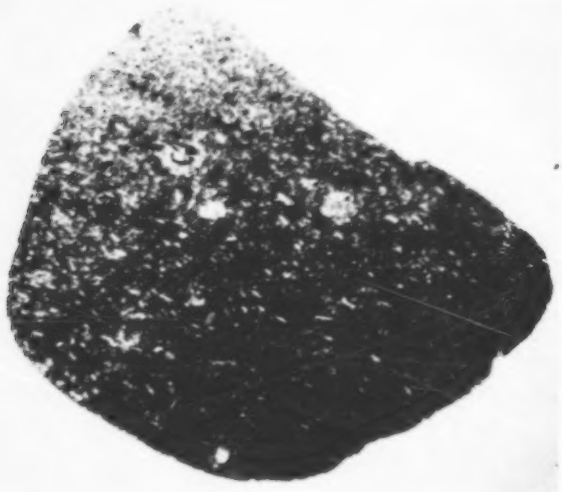


Figure 17. Photographie d'un grain de roche volcanique basique (LLP).

TABLEAU I
Pétrographie des échantillons par secteur

	Grauwacke	Sediment a grain fin	Calc.crist. ou marbre	Granodiorite	GrD a Hornbl.	Gabbro	Flow Rock	Tuf	Schiste (metam.)	Quartzite	Amphibolite	Pyroxenite	Greenstone	Nombre echantillons
I Kluane	2	1	3	1	2	7	7		7	3			2	5
IIa Cultus	2					1	3		7	1	2			5
IIb F July		1		1		3	2		4	2	2	1		3
IIc Jarvis	1	5	2	2		1	2		2	5				2
IIIa S Aish.	5	1		5		5	4		14	1	3		1	8
IIIb entre Sek. et Aish.	3	1		7	2	3	9		3	3	1			9
IIIc N Aish.	3			13	1	1	19	6	18	7	3			13
IIId MacIntosh	3			5	2		4	2	5		6	1		8
IV delta A.C.				2		1	7		11	13	3			6
Va Gladstone VC				1					22	2				5
Vb Gladstone RL				4	2	2			9		3			4
Vc Gladstone WL				6	1	2	1		8	1	4			5
Vd Gladstone GT				10			1		5					4
VI Albert/ Rock.				12	2					1				3
VII O Sek.				3	1				5	1	1			2
VIII Mars Cr.				5	1		3		3		1			3
RV2						4			3					1
RV1	1			2	1				8					1
LCM	1	1		1			1		5				2	4
VH1				2		1	1		4				1	1

correspondent à la roche en place le long de la rive est du lac Kluane. La quasi-absence de granodiorite indique que les Montagnes côtières ne constituaient pas la source principale du lobe de Kluane. Nous préférons ne pas donner d'interprétation pour les grains de quartzite, car vu leur petite taille ils peuvent aussi bien correspondre à des veines de quartz dans des schistes qu'à une roche-mètre effectivement de quartzite.

Le groupe échantillonné dans la vallée de Jarvis Cultus (II) présente un profil comparable à celui de Kluane, confirmant qu'il s'agit du même lobe; mais avec certaines particularités: Cultus (a), situé le plus à l'aval, présente essentiellement la roche locale (schistes) alors que la rivière Jarvis (c), le plus à l'amont, est davantage orienté sur les roches sédimentaires, et la rivière Fourth of July (b), vallée affluente du Nord, donne plusieurs gabbros qui s'expliqueraient par la localisation à proximité d'affleurements de roches basiques et ultra basiques décrits par Muller (1967) au contact entre deux unités de schistes.

L'ensemble des échantillons provenant de la région située à l'est du lac Sekulmun (groupe III) se caractérisent par des grauwackes, granodiorites, amphibolites ainsi que des roches volcaniques et métamorphiques, puisque ces cinq types se retrouvent dans chacune des sous régions. Les grauwackes indiquent les St Elias comme source extra-régionale; et il faut remarquer ici que le transport s'est effectué sur des distances de l'ordre de 150 km pour les grains situés dans la vallée de MacIntosh et au nord du lac Aishihik, ce qui indique l'importance de la masse de glace qui constituait le lobe d'Aishihik. Les granodiorites proviennent des Montagnes côtières, et du batholite de la chaîne Ruby et, pour les dépôts les plus au nord, de la ceinture de granodiorite à hornblende; il est donc normal de trouver cette roche en abondance. Les roches métamorphiques constituent la roche en place entre les deux lacs et au S.O. du lac Aishihik, et forment une seconde bande plus au sud, d'où leur abondance dans les échantillons. L'importance des roches volcaniques, avec l'apparition de grains de tuf, indique que les affleurements le long du lac Aishihik et dans le secteur de MacIntosh ont suppléé significativement aux dépôts. Quant aux amphiboles, elles se retrouvent sporadiquement dans tout le plateau de Kluane, mais ne sont pas décrites dans les St Elias. Leur absence le long du lac Kluane, leur apparition dans la vallée Jarvis-Cultus et leur présence systématique dans les dépôts du lobe d'Aishihik est donc justifiable.

Si l'on examine à présent les groupes d'échantillons provenant du coeur de la chaîne Ruby, on constate que la lithologie locale prend toute l'importance. Venus Creek (VC, Va), affluent de Gladstone Creek et située dans la ceinture de schistes à biotite, présente 22 roches métamorphiques sur 25 grains analysées; la vallée du Gladstone, dont le bassin couvre des granodiorites et des schistes, donne des échantillons bi-modaux (RL, WL: Vb et c), et dans Isaac Creek (Vd), prolongation à l'est de la vallée Gladstone, où les granodiorites affleurent, ceux-ci dominent nettement les schistes, qui proviennent de l'amont (GT). Le Groupe Albert Rockslide Creeks (VI), situé au coeur du batholite de granodiorite, produit 14 grains de ce type sur 15 analysés. Les tills situées à l'ouest de Sekulmun (groupe VII) sont typiquement bi-modales (granodiorites schistes), et correspondraient donc à des glaciers locaux; dans Mars Creek en revanche (groupe VIII) on trouve des roches volcaniques, ce qui indiquerait un apport extérieur. Mais le fait qu'elles soient de composition basique et altérées nous porte à croire qu'elles proviennent, comme dans le cas des gabbros de la Formation Fourth of July, de la zone de contact entre deux unités de schiste. La confusion proviendrait de la taille des grains, et de la finesse de la texture. Ceci devient d'autant plus probable que nous retrouvons plusieurs gabbros dans l'échantillon RV2, situé à proximité. Cette zone de contact à roches basiques affleure au sommet de la série de pics qui séparent les vallées Gladstone et Mars de Cultus et Jarvis. Or ceux-ci étaient situés au-dessus de la limite des glaces lors de la dernière glaciation, et ont donc pu fournir par gélivation une quantité importante de débris tant sur le flanc nord que le flanc sud de cette ride.

La moraine RV2 se caractérise immédiatement par la présence d'un grain de grauwacke, qui prouve que la glace qui s'écoulait dans Jarvis avait une épaisseur suffisante pour déborder à l'intérieur de la chaine via les vallées de Twelth of July et/ou Ruby. L'absence de grauwacke plus à l'intérieur de la chaîne, ainsi que l'altitude et l'étroitesse des cols portent à croire que ce débordement a engendré une mince langue de glace d'une quinzaine de km seulement.

Les échantillons récoltés dans la moraine LCM, située dans la vallée Gladstone à une vingtaine de km du lac Kluane, se révèlent très instructifs: la diversité de la pétrographie, et surtout la présence de grauwacke indiquent une affiliation au lobe de Kluane, mais avec des roches métamorphiques plus abondantes. Nous pensons que cette moraine très puissante constitue la limite de l'extension du lobe de Kluane à l'intérieur de la vallée Gladstone, puisqu'elle montre une source extra-régionale, que nous ne retrouvons plus à l'est dans la vallée, avec un enrichissement en roches métamorphiques locales sur les derniers km de parcours. Nous avons tenté de répéter ce raisonnement pour la gigantesque moraine située dans la vallée de la rivière Talbot, mais les résultats sont peu concluants, dû au fait que nous ne possédons qu'un seul échantillon. Il existe cependant un indice, la présence d'un grain de roche verte, dont la source est également dans les St Elias. Étant donné la longueur du trajet effectué par la langue de glace dans une vallée de plus en plus étroite, il est normal de voir la source extra-régionale se réduire fortement par rapport à la lithologie locale.

Les échantillons récoltés près de l'embouchure d'Albert Creek (IV) montrent que la pétrographie peut aider à reconstituer des séquences de déglaciation. Les photographies aériennes du secteur suggèrent la présence de sédiments deltaïques coincés entre deux zones à topographie typique de glace morte. Nous avions pour interprétation que très tôt lors de la déglaciation, les langues actives s'écoulant dans les vallées de Sekulmun et Aishihik ont cessé de se rejoindre, laissant entre elles une zone de glace morte. Le centre étant le plus ancien, a fondu plus rapidement, ouvrant la possibilité aux eaux de fonte du glacier d'Albert Creek (lui aussi en phase de déglaciation) de s'écouler dans cette zone déjà innondée. Il s'est alors formé un delta, dont les sédiments proviennent du glacier d'Albert Creek. Cette hypothèse est à présent confirmée, puisque les sédiments récoltés en bordure des lacs sont typiques du lobe d'Aishihik, avec source extra-régionale, tandis que les échantillons récoltés dans ce delta montrent une abondance de roches volcaniques et métamorphiques, constituants locaux, peu de granodiorite et une absence totale de roches sédimentaies. Leur source est donc

plus que probablement le N.O., c'est-à-dire l'ancienne vallée d'Albert Creek.

Conclusion

Par la pétographie des sables grossiers et graviers fins, nous avons prouvé qu'il était possible de distinguer les grands écoulements glaciaires des glaciers locaux, c'est à dire dans notre cas le lobe d'Aishihik, celui de Kluane, et les glaciers internes à la chaîne Ruby. Les dépôts correspondant aux grandes langues se caractérisent en effet par leur diversité pétrographique et la présence de roches extra-régionales (dans notre cas les grauwackes), tandis que les dépôts de glaciers locaux présentent un profil uni- ou bi- modal, où le(s) mode(s) correspond(ent) aux affleurements locaux (granodiorites et/ou schistes). Chacun des lobes et glaciers locaux se caractérise donc par un cortège pétrographique distinct, pour peu que nous possédions quelques échantillons d'un même secteur.

Le cas de la moraine LCM montre que cette pétrographie peut servir à délimiter l'extension d'un lobe à l'intérieur d'une chaîne, et celui du delta d'Albert Creek est un exemple de l'utilité de la pétrographie dans la reconstruction des séquences de déglaciation. Il faut signaler enfin que cette étude pétrographique de la fraction grossière n'est qu'un élément des informations contenues dans les sédiments. Nous tenterons ensuite de raffiner ces résultats par l'analyse des minéraux lourds (44 à 250μ) de ces échantillons ainsi que d'autres sables fins de la région.

Remerciements

L'étude sur le terrain a été financée par le groupe de recherche nordique ainsi que les subventions du CNRSG de notre superviseur, M.-A. Geurts.

Nous exprimons toute notre gratitude à J. Mrazek pour la préparation des lames minces, A. Lalonde et J. Mrazek pour leur aide précieuse lors de l'identification des grains.

Nos plus vifs remerciements vont à M.-A. Geurts pour ses conseils judicieux, ses encouragements fréquents et son aide financière.

Références

Adams, A.E., MacKenzie, W.S., and Guilford, C. 1984: Atlas of Sedimentary Rocks Under the Microscope. J. Wiley and Sons, New York, 104 p.

Bostock, H.S. 1948: Physiography of the Canadian Cordillera, with special reference to the area north of the fifty fifth parallel. Geological Survey of Canada, Memoir 247, 103 p.

Bostock, H.S. 1966: Notes on glaciation in Central Yukon Territory. Geological Survey of Canada, Paper 65-36, 18 p.

Douglas, R.J.W. 1980: Map 1398A MacMillan River, Yukon, District of Mackenzie-Alaska, 1:1 000 000, geological atlas sheet 105,115.

Hughes, O.L. 1967: Surficial geology studies, Aishihik Lake map-area. Geological Survey of Canada, in Report of Activities, Part A, Paper 67-1A:48-49.

Hughes, O.L. 1967: Surficial geology, Aishihik Lake, Yukon Territory, (115H). Geological Survey of Canada, in Report of Activities, Part A, Paper 68-1A:168.

Hughes, O.L., Campbell, R.B., Muller, J.E. & Wheeler, J.O. 1969: Glacial limits and flow patterns, Yukon Territory, south of 65 North Latitude. Geological Survey of Canada, Paper 68-34, 9 p.

Kindle, E.D. 1953: Dezadeash map-area, Yukon Territory. Geological Survey of Canada, Memoir 268, 59 p.

MacKenzie, W.S. & Guilford, C. 1980: Atlas of rock-forming minerals in thin section. Longman Group Ltd., London, 98 p.

MacKenzie, W.S., Donaldson, C.H. & Guilford, C. 1982: Atlas of igneous rocks and their textures. Longman Group Ltd., London, 148 p.

Muller, J.E. 1967: Kluane Lake map-area, Yukon Territory (115G, 115F E1/2) Geological Survey of Canada, Memoir 340, 137 p.

Prest, V.K. 1984: Late Wisconsinan glacier complex. Geological Survey of Canada, Map 1584A.

Tempelman-Kluit, D.J. 1974: Reconnaissance geology of Aishihik Lake, Snag and part of Stewart River map-areas, West central Yukon (115H, 115F, 115G & 115K). Geological Survey of Canada, Paper 73-41, 97 p.

CARACTÉRISTIQUES PHYSIQUES ET CHIMIQUES DE TROIS TOURBIÈRES SUBARCTIQUES DANS LA RÉGION DE SCHEFFERVILLE, QUÉBEC

Marisa Ditata

Département de Géographie, Université McGill, Montréal, Québec H3A 2K6

Niveau: Maîtrise

Résumé

Une description détaillée de trois tourbières subarctiques a été faite dans la région de Schefferville. Les buts de cette description étaient de connaître la distribution et l'agencement de divers caractères de la tourbe. En plus, l'aspect évolutif des tourbières selon les différentes topographies et lithologies est considéré.

À partir de cartes détaillées des sites d'études, de nombreaux transects ont été établis afin d'obtenir un recouvrement complet des sites. L'échantillonnage s'est fait selon les unités homogènes de végétation le long des transects. Une description détaillée des profils de sol a suivi celle de la description générale des environs des sites d'échantillonnage. Les horizons ont été décrits selon leur épaisseur, leur degré de décomposition, couleur et type de matériel. Des mesures de pH ont aussi été prises ainsi que plusieurs remarques. Des échantillons de tourbe ont été rapportés pour effectuer des analyses plus détaillées telles le contenu en cendre et en fibres, la capacité d'échange cationique, les acides humiques et fulviques. . . Toutes ces informations serviront à la conception d'une vision tri-dimensionnelle des lieux ainsi qu'à l'élaboration d'une séquence évolutive pour chacune des tourbières.

Mots-clés: Tourbières, profils de sol, vision tridimensionnelle, subarctique.

Abstract

A detailed description was made of three subarctic peat-bogs in the Schefferville region. The purpose was to determine the distribution and organization of various characteristics of the peat, and also to study the evolution of the peat-bogs in different topographical and geographical environments.

On the basis of detailed maps of the study sites, a number of transects were made, to ensure complete coverage of the sites. The sampling was made on the basis of homogeneous units of vegetation along the transects. A detailed description of soil profiles was prepared after the environment of each sampling location had been described in general terms. Horizons were described in terms of their depth, their degree of decomposition, colour and type of material. pH measurements were also taken and notes made for each horizon. Soil samples were brought back for more detailed analysis of such features as ash and fibre content, capacity for cation exchange, humic acids. The accumulated data will be used to arrive at a three-dimensional concept of the sites and to work out a development sequence for each peat-bog.

Key words: Peat-bogs, soil profiles, three-dimensional concept, subarctic, pH.

Introduction

Il existe peu d'étude sur les caractéristiques physiques et chimiques des tourbières ou autres milieux marécageux. Dans la présente étude, je me suis attardée à trois tourbières subarctiques différentes au point de vue de leur localisation et de la lithologie sur lesquelles elles reposent dans la région de Schefferville, du Québec nordique. J'ai voulu savoir les caractères physiques et chimiques que pouvaient avoir différents types de tourbe provenant de trois milieux précis. Le travail fait jusqu'à présent se limite aux caractères physiques descriptifs de la tourbe. Par les résultats obtenus, une étude approfondie s'avère nécessaire et a été entreprise. On touche entr'autre aux analyses se rapportant aux cations et aussi à celles sur les acides humiques et fulviques. Par la suite, avec toutes ces informations, je serai en mesure de comprendre mieux l'évolution temporelle et spatiale de ces lieux.

Les sites d'études

Les sites d'étude sont respectivement situés à 7, 20 et 25 km de la ville de Schefferville, Québec nordique (54° 43′ N, 66° 42′ W). La figure 1 représente la localisation des sites d'étude. Il s'agit de trois tourbières minérotrophes, différentes par leur situation topographique et par la lithologie de leur plancher.

Selon la classification morphologique de Grondin et Ouzilleau (1980), la tourbière Pelletier est une unité à mares étroites et parallèles. Elle se distingue par la présence de nombreuses mares et de lanières longues, étroites et parallèles. Les mares sont en général peu profondes (moins de 50 cm) et se situent sur tout vers l'aval. Les lanières sont recouvertes d'herbes en majeure partie. Le type de roche sous cette tourbière est du schiste. La profondeur moyenne du matériel tourbeux est d'environ 100 cm; il est peu épais en amont, atteint son épaisseur maximale au centre de la tourbière et diminue graduellement jusqu'au lac.

La tourbière Iron Arm peut être décrite par deux unités morphologiques: uniforme herbacée sans ruissellement apparent à la surface et, aux portions centrales, à mares étroites et parallèles. Son couvert végétal est dominé par le *Carex limosa* et *Scirpus cespitosus*. La profondeur moyenne de la tourbe est de 125 cm et consiste en un matériel bien décomposé et consolidé. Ici aussi, le schiste est le type de roche qu'on retrouve dans les environs de la tourbière.

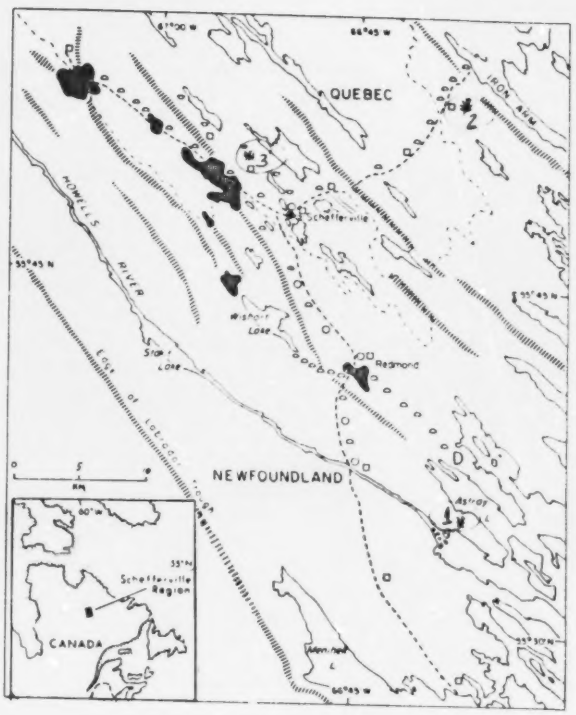


Figure 1 Localisation des sites d'études
nº 1 Tourbière Astray
nº 2 Tourbière Iron Arm
nº 3 Tourbière Pelletier

Le troisième d'étude est la tourbière Astray. On la divise en deux sections: une première riche en éléments nutritifs et soutenue par de la dolomite et une seconde plus pauvre donc plus acide et soutenue par du schiste. Cette dernière section est située dans la partie nord de la tourbière. Les laîches et quelques éricacées dominent le couvert végétal. On retrouve aussi des buttes de sphaigne, ce qui donnent une microtopographie à la tourbière. La section riche en éléments nutritifs est située dans la partie sud de cette même tourbière. Ici, c'est le *Carex aquatilis* qui domine la végétation. De plus, on peut remarquer que la nappe phréatique affleure à tous ces endroits. Dans l'ensemble de la tourbière, le matériel tourbeux a une épaisseur moyenne de 138 cm et il est bien consolidé et décomposé.

Méthodologie

Rappelons ici les buts de ces descriptions. À partir de cartes détaillées des trois sites d'études, on a voulu avoir une perspective de la tourbe en profondeur en vue de connaître la distribution et l'agencement de ses divers caractères. On trouvera en figures 2,3, et 4 les croquis des sites d'étude.

Deux des trois sites avaient déjà été cartographiés. Le troisième site, c'est-à-dire la tourbière Pelletier, devait être cartographié d'une façon simple et efficace, et avec une échelle comparable à celle des cartes des deux autres sites. Une ligne de référence a été tirée à partir d'un point central à l'amont en direction opposée. Cette ligne se devait d'être

Figure 2. Tourbière Astray

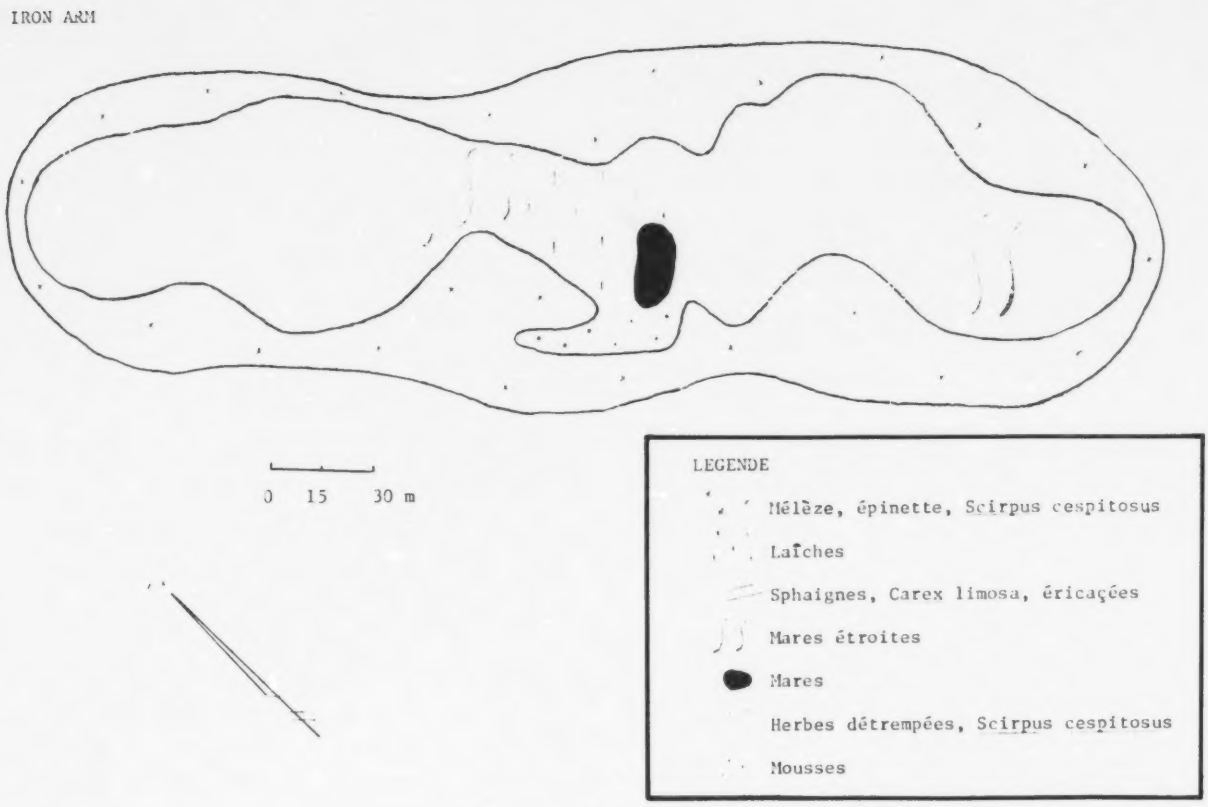


Figure 3. Tourbière Iron Arm.

le plus au centre possible afin d'être visible sur une plus grande distance. De là, des carrés de 10m x 10m ont été dressés à partir de cette même ligne de référence vers les extrémités afin de pouvoir cartographier les contours et limites de la tourbière ainsi que les unités végétales dominantes. L'échelle choisie de la carte est d'environ 1:1500 et se veut assez précise pour ce genre de description. De plus, une carte des profondeurs du matériel tourbeau a été dressée pour avoir une idée de la topographie souterraine de la tourbière.

Donc, à partir de ces cartes détaillées, de nombreux transects perpendiculaires au tracé des tourbières ont été établis tous les 10 mètres s'il y avait d'importants changements à la surface sinon un transect tous les 20 à 30 mètres était suffisant et ce, afin d'obtenir un recouvrement complet des sites. Par la suite, sur ces mêmes transects, des coupes de sol ont été faites afin de décrire la tourbe en profondeur. L'échantillonnage des profils s'est fait selon les unités homogènes de végétation ou ailleurs selon les évidences sur le terrain. Une description détaillée des profils de sol a suivi celle de

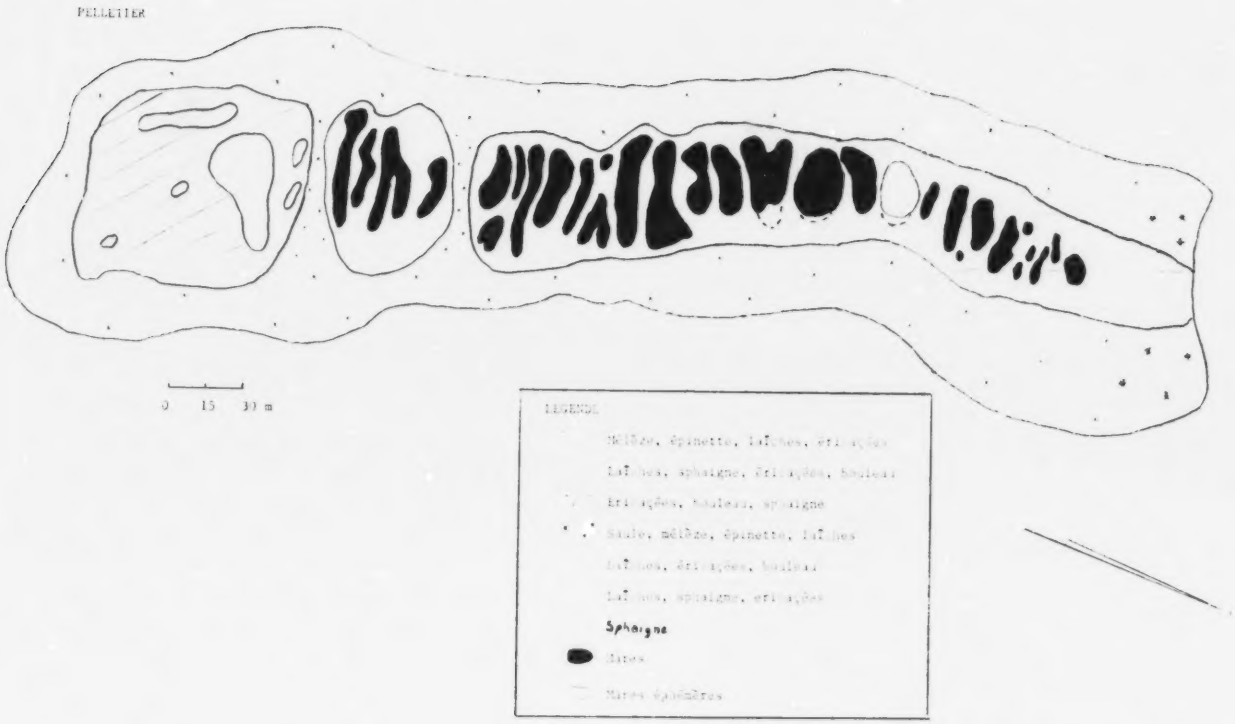


Figure 4. Tourbière Pelletier.

la description générale des environs des sites d'échantillonnage. Citons que l'appareil utilisé pour cet échantillonnage était un carrotier de type Sonde Russe collectant la tourbe par tranche de 50 cm. Les horizons organiques ont été décrits selon leur épaisseur, leur degré de décomposition selon l'échelle von Post (Anonyme, 1972), leur couleur selon la charte Munsell et le type de matériel dont ils sont l'origine. Des mesures de pH selon les horizons ont été prises pour chacun des profils. Pour ce faire, environ 50 cm^3 de tourbe humide ont été mis dans un bécher dans lequel on a ajouté une certaine quantité d'eau distillée pour atteindre le point de saturation. Les mesures de pH ont été prises une heure après cette manipulation grâce à un pH-mètre de modèle Fisher no. 156. Toutes ces informations ont été retranscrites sous forme de tableau afin de pouvoir comparer les différents profils de tourbes.

Discussion

Bien que ces sites se ressemblent beaucoup au premier coup d'oeil, il n'en reste pas moins qu'ils sont différents au point de vue de leur composition chimique et de leur évolution.

Tous les profils de tourbe considérées dans cette étude ont été décrits de la surface jusqu'au sol minéral dans la plupart des cas. Quelques fois, un obstacle tel une lentille de glace ou une roche nous empêchait de creuser d'avantage.

Dans le cas de la tourbière Astray, deux grandes unités se dégagent. La tourbière est différente dans ses deux extrémités. La partie située au sud est recouverte surtout par le *Carex limosa* et *rostrata* et est beaucoup plus acide dans son ensemble que la partie nord de la tourbière qui est dominée par le *Carex aquatilis*. La roche sous-jacente explique en partie cette différence d'acidité: la partie sud est sur du schiste tandis que la partie nord est sur la dolomite. Le contact de ces deux lithologies est notée par une rupture de pente importante. On note aussi dans l'ensemble de la tourbière que le matériel tourbeux est foncé et bien détrempé. Ce sont des horizons fibriques (Of) et mésiques (Om) qui dominent dans les profils. Dans certains, le matériel est tellement bien décomposé que rien est identifiable alors il s'agit d'un horizon humique (Oh). En général, on peut toujours distinguer des restes de végétaux soient des feuilles, morceaux de bois, fibres et même parfois des laîches. Le sol minéral était de couleur grise et composé de matériel fin, ce qui correspond à une argile. En plus, cette dernière contenait beaucoup de petites roches. Notons aussi que le sol minéral était gleyifié.

La tourbière Iron Arm fait environ 330m de long et est assez uniforme dans son ensemble. Une extrémité est dominé par certaines éricacées, de la sphaigne et du *Carex limosa*. On y retrouve aussi quelques mares étroites et parallèles. Cette portion fait suite à une zone dominée par du *Scirpus cespitosus* et de la mousse. Cette extremité est aussi beaucoup plus détrempée que la zone à *Scirpus cespitosus*: le niveau de la nappe phréatique est supérieur à celui de la tourbe.

Cependant, le matériel tourbeux y est un peu plus décomposé; alors ce sont en majorité des horizons mésiques (Om) que nous avons observés. Les mesures de pH varient de 4.2 à 6.0: les parties les plus acides se trouvant à l'amont et plus on se déplace vers la partie détrempée, c'est-à-dire vers l'aval, plus les mesures de pH augmentent et ce, dans tous les horizons décrits dans les profils. On remarque que les mesures de pH prises le long des profils tendent à diminuer, c'est-à-dire que le sol devient de plus en plus acide en profondeur et ce, jusqu'à l'horizon qui précède le sol minéral. A cet endroit, les mesures de pH remontent un peu soit de quelques dixièmes. Le sol minéral est une argile contenant du sable fin. Elle est de couleur grise foncée et ne semble pas avoir des signes de gleyification.

Le troisième site d'étude est la tourbière Pelletier. Particulière dans sa physionomie, elle reste cependant semblable aux autres par ses profils. Dans l'ensemble de la tourbière, la tourbe est bien consolidée et bien détrempée. Cependant à proximité d'une mare, la colonne de tourbe était souvent incomplète à cause du trop haut niveau de la nappe phréatique.

En ce qui concerne les profils, le matériel est peu à moyennement décomposé. La couleur du matériel tourbeux reste cependant assez foncée: on rencontre souvent la notation de 10YR 2/2 et 10YR 3/1 pour une tourbe détrempée. Le matériel en décomposition est seulement identifiable dans le premier horizon de surface; dans ceux qui suivent, les restes de végétaux sont les seuls indices pour une identification des végétaux. Pour le pH, ses mesures varient de 4.0 à 5.4. Cette dernière mesure a été prise à l'aval de la tourbière, dans un profil échantillonné tout près du lac. Le sol minéral, une argile presque pure, a une particularité spéciale. Celle qu'on retrouve aux contacts des deux matières est de couleur brunâtre (10YR 4/2) et a une épaisseur variant de 2 à 5 cm; elle est aussi gleyifiée. Celle qu'on retrouve en dessous par contre, est de couleur rougeâtre (10R 4/4) et ne porte aucun signe de gleyification. Ces dernières caractéristiques ont été retrouvées dans presque tous les profils sauf ceux dans une partie gélée de la tourbière où on n'a pu atteindre le sol minéral.

Conclusion

Les buts de cette étude étaient de toucher à l'aspect descriptif et évolutif des tourbières subarctiques. On a voulu connaître aussi la distribution et l'agencement de divers caractères autant physiques que chimiques de la tourbe.

Je me suis aperçue qu'en faisant des descriptions physiques des profils de tourbe les différents caractères de la tourbe n'étaient pas mis en évidence. Ceux qui ressortaient par contre, étaient la distribution des différents horizons basée sur le degré de décomposition de la tourbe et le type de matériel qui composait cette dernière. Pour amplifier ces caractères, des mesures de pH ont été prises sur tous les horizons des profils. Étant donné l'importance des variations dans les mesures de pH, des analyses plus approfondies seront faites sur des échantillons de tourbe rapportés en laboratoire. Avec l'information déjà connue, il sera facile d'avoir une perspective en trois dimensions des caractéristiques de la tourbe. Avec celle qu'on obtiendra avec les analyses en laboratoire, on saura formuler des hypothèses concernant l'évolution temporelle et spatiale de ces lieux.

Remerciements

Ce projet de recherche a été subventionné par le Département des Affaires Indiennes et du Nord. Le projet s'est tenu grâce à la Station de Recherche Subarctique de McGill, à Schefferville, au Québec. L'auteur voudrait remercier les personnes suivantes pour leur aide sur le terrain: D. Wilkenson, E. Albert, D. Barr et R. Muller-Wille.

Références

Anonyme. 1972. Classification Canadienne des sols. Ministère de l'Agriculture du Canada. Ottawa.

Grondin P. et J. Ouzilleau. 1980. Les tourbières du sud de la Jamésie, Québec. GPQ. 34(3):267-299.

ON THE CHEMICAL INFLUENCE OF A DECAYING SUBARCTIC LAKE ICE COVER, SCHEFFERVILLE, QUEBEC

Peter T. Doran

Department of Geography, Queen's University, Kingston, Ontario K7L 3N6

Level: Bachelor's

Abstract

A study was undertaken on Knob Lake (54°47′30″N, 66°48′35″W), near Schefferville, Quebec, to determine the chemical influence of a melting subarctic ice cover. Conductivity and major cations, were used as indicators of chemical change at a near shore and deep hole site.

A pre-breakup chemical analysis of the ice cover revealed extremely low conductivities, and near absence of Ca^{++} and Mg^{++} in this moderately dilute lake (conductance of approximately 75 umhos/cm and pH of approximately 6.5) suggesting differential exsolution of the ions. A regression equation derived from organic terrain in the watershed was used to predict Ca^{++} and Mg^{++} in both the ice cover and water column, and was found suitable only for the latter. As the melt proceeded the diluting effect of the ice cover encroached lower into the water column indicating a density-induced downwelling. Furthermore, benthic conductivities were greater at the deephole than near shore site suggesting a downslope migration of solute rich waters.

Finally, a chemical mass balance showed that the ice cover dilutes all levels of the lake to a certain point, when the ice itself becomes insignificant, volumetrically.

Key words: Lake ice, break-up, conductivity, major cations, subarctic, Quebec/Labrador.

Résumé

Une étude a été entreprise au lac Knob (54°47′30″N, 66°48′35″0.), près de Schefferville, Québec, afin de déterminer l'influence chimique d'une couche de glace subarctique fondante. La conductivité et les principaux cations ont été utilisés en tant qu'indicateurs de changements chimiques à une station près de la rive et une autre à plus grande profondeur.

Une analyse chimique de la couche de glace avant le morcellement a indiqué des valeurs très faibles de conductivité, et une quasi-absence de Ca^{++} et Mg^{++} dans ce lac modérément dilué (conductivité d'environ 75 umhos/cm et pH d'environ 6,5) ce qui semble indiquer une exsolution différentielle des ions. Une formule de régression dérivant de terrain organique du bassin versant a été utilisée afin de prédire la teneur de Ca^{++} et Mg^{++} dans la couche de glace et dans la colonne d'eau, et ne fut appropriée que dans le dernier cas. Comme la fonte progressait, l'effet diluant de la couche de glace continuait plus en profondeur, indiquant une progression en profoundeur induite par la densité. De plus, les conductivités benthiques étaient supérieures en profoundeur comparativement à la rive, laissant supposer une migration vers les bas des eaux riches en solutés.

Finalement, une balance de la masse chimique a indiqué que la couche de glace dilue tous les niveaux du lac jusqu'à un point tel où la glace n'est plus significative, volumétriquement.

Mots-clés: Glace lacustre, morcellement, conductivité, cations majeurs, sub-arctique, Québec/Labrador.

Introduction

Knowledge of the ionic behaviour of arctic and subarctic lakes during break-up is scanty. Past studies have often monitored a lake's behaviour over the entire year, while omitting the period during which the ice was considered unsafe.

During ice formation the processes of exsolution and slushing can create an ice sheet that is vertically dissimilar in ionic strength (Adams and Lasenby, 1985; Barica and Armstrong, 1971). Black ice, being essentially frozen lake water, is relatively pure as a result of exsolution. Furthermore, water immediately below the forming black ice becomes increasingly solute rich (Adams and Lasenby, 1985). It is this water that is incorporated in snow depression slushing, which is common in high snowfall areas. White ice can also form by a melting and refreezing of the ice snow pack and even slushing of a snow-free ice cover will result in a white coloured ice (Kingsbury, 1983). Depending on the formation process involved, white ice can have conductivities (an approximation of total dissolved solids i.e. ionic strength) as high as 70 umhos cm^{-1} (Adams and Lasenby, 1985), while black ice conductivities are commonly less than 10 umhos cm^{-1} (Adams and Lasenby, 1985; Gunn and Keller, 1985; Kingsbury, 1983).

As an ice cover melts it appears that its contribution (or dilution) of ions to the water body will depend on the proportion of white to black ice, and hence the amount of snowfall. Evidence to date (Gunn and Keller, 1985) suggests that regardless of ice proportions, ice melt will dilute surface waters.

The purpose of the present study is to observe chemical changes in a subarctic lake near Schefferville, Quebec, during the break-up of May — June, 1985 as represented by changes in conductivity and specific ions.

Regional environment

The Schefferville region lies in the part of the Canadian Shield known as the Labrador Trough (Fig. 1). This is a zone of more or less metamorphosed geosynclinal sediments which occupies the central portion of the Labrador-Ungava Peninsula of Eastern Canada.

It has been shown (Drake, 1981) that the geology of the area exerts a control on the groundwater. For dissolved solids the most common type of control is exerted by mineral solubility.

The Schefferville region has a climate which is well suited for ice growth (mean annual air temperature = −4.9°C) and heavy snowfall (mean annual snowfall = 377 mm). The latter makes this a strongly white ice environment.

Vegetation in the region plays a unique role in both the timing of the hydrologic cycle and the chemistry of the water reaching the lakes. The dense carpet of lichens, which is a predominant feature of the area, can hold up to 400 times its dry weight in water (Findlay, 1966). It can only be assumed that this seriously alters the pathways water will take. Furthermore, lichens are non-vascular plants, therefore evaporation is reduced.

The Schefferville region is also characterized by numerous bogs and fens and their related vegetational types. The effects of these wetlands are variable. Gorham *et al* (1984) found that in catchments composed of both terrestrial and aquatic ecosystems, the latter contribute disproportionately to loss of water from the catchment and therefore dissolved materials.

Lake morphometry

Knob Lake (54°47′30″N, 66°48′35″W) lies directly south of the town of Schefferville. Its long axis is 2500 m and is oriented in the general direction of the Labrador Trough (NW-SE). Knob Lake is relatively deep for the area with a mean depth of 5.63 m and a maximum depth of 14.94 m. It is sub-circular (shore development = 2.05) which is not characteristic of lakes in the area, however it is of average size (area = 1.92 km).

Methods

Two ice blocks were extracted from Knob Lake at the sites shown in Figure 2. This was accomplished using a Snabb spoon drill and ice saw. Once extracted the blocks were sectioned at 5 cm intervals from the black ice/white ice interface using a swede saw, rinsed with deionized water, placed in pre-rinsed polyethylene bags, and allowed to thaw. Each sample was allowed to melt and then poured into 125 ml acid-washed nalgene bottles (four subsamples were made for each interval). Triplicate conductivity readings were made at 25°C from three of these subsamples using an Electro Mark Analyzer (Markson Science Inc.). The fourth subsample was acidified with reagent grade nitric acid (HNO^3) for later specific ion determination. The major cations (Ca^{++}, Mg^{++} Na^{+}, and K^{+}) were analyzed by atomic absorption and flame emission photometry, using a Varian Atomic Absorption Spectrophotometer, model A.A. 375.

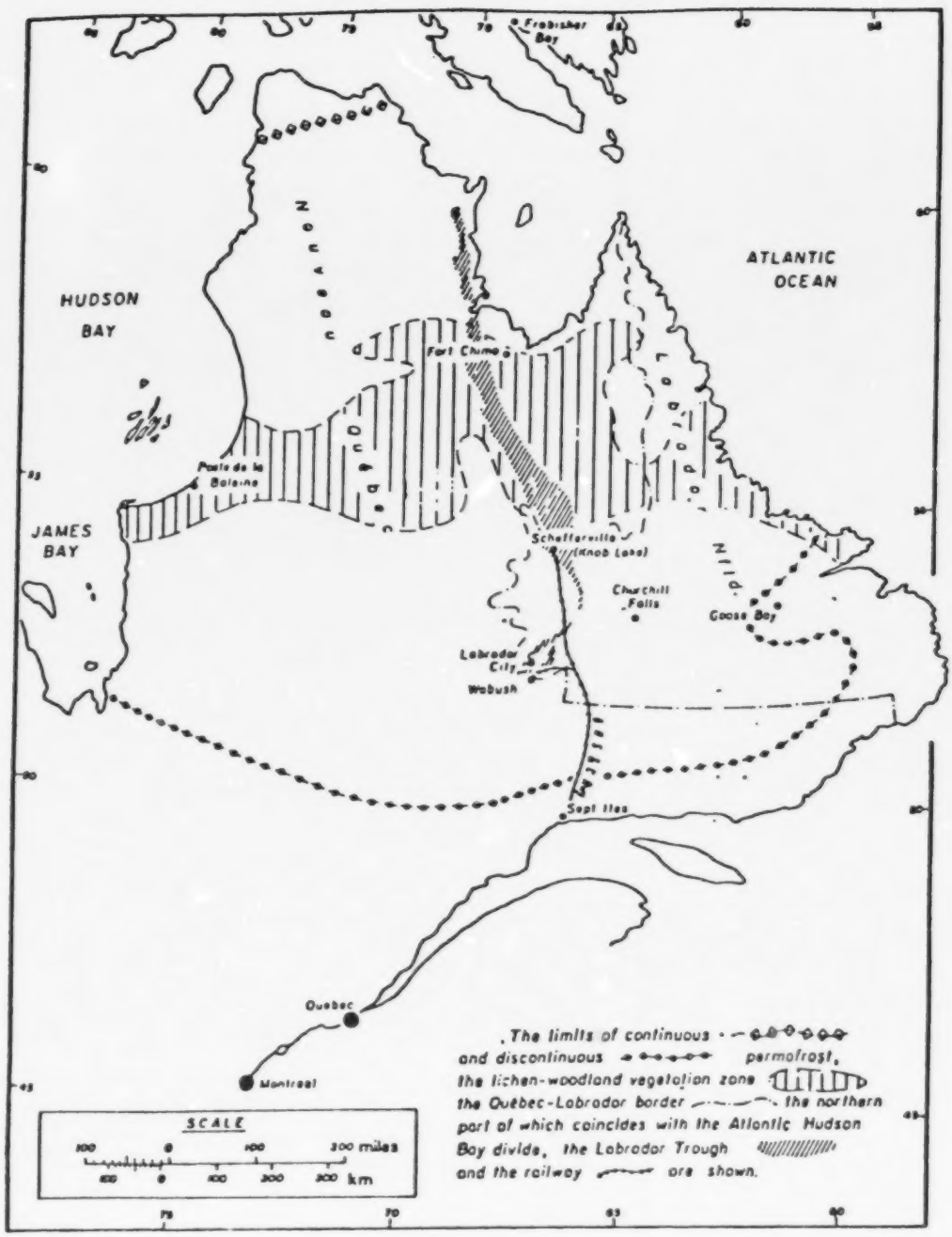


Figure 1. Map of Labrador/Ungava showing relevant features (modified from Adams (1982)).

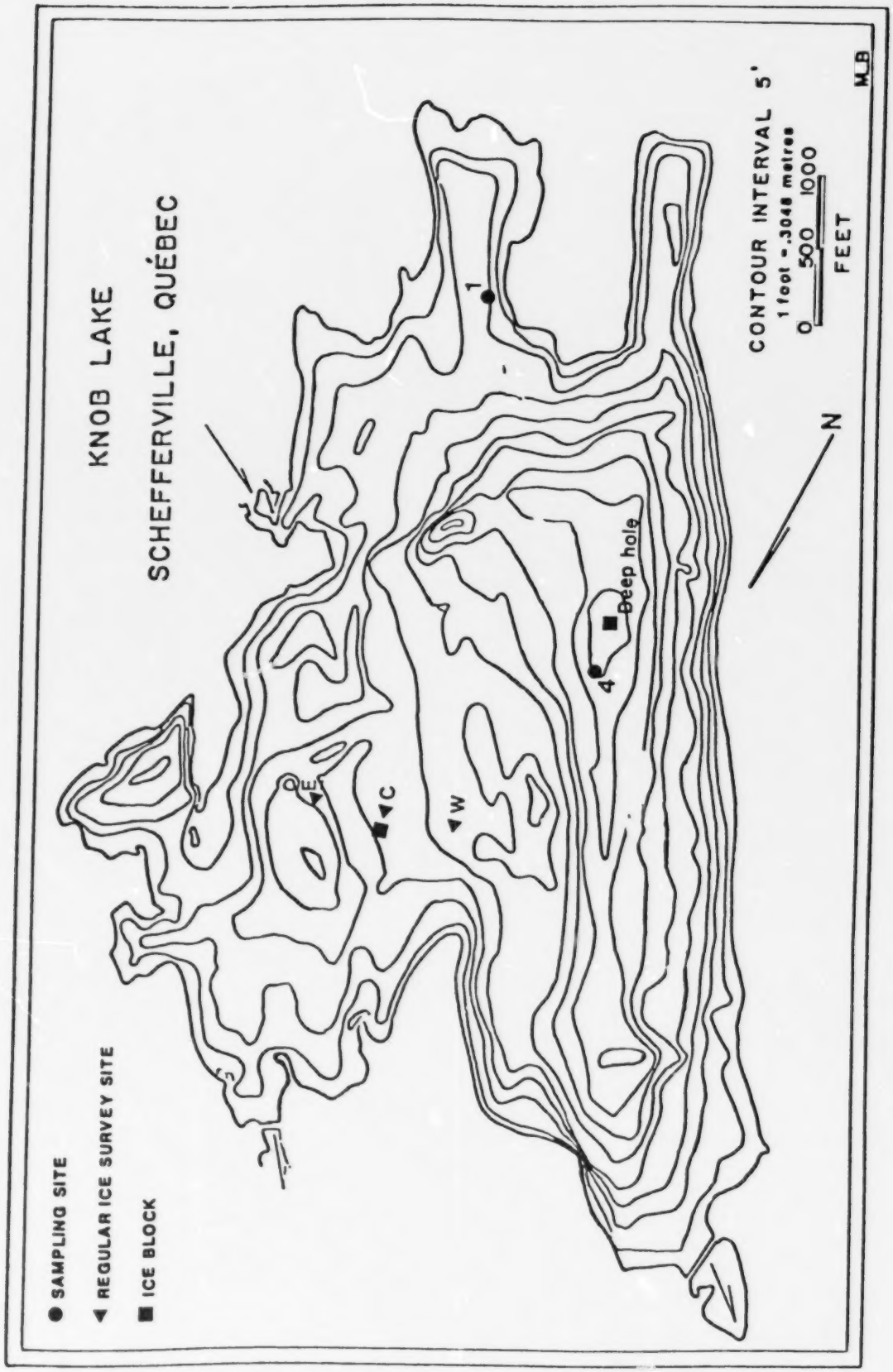


Figure 2. Map of Knob Lake water sampling sites, and ice block sites (modified from Bryan (1964)).

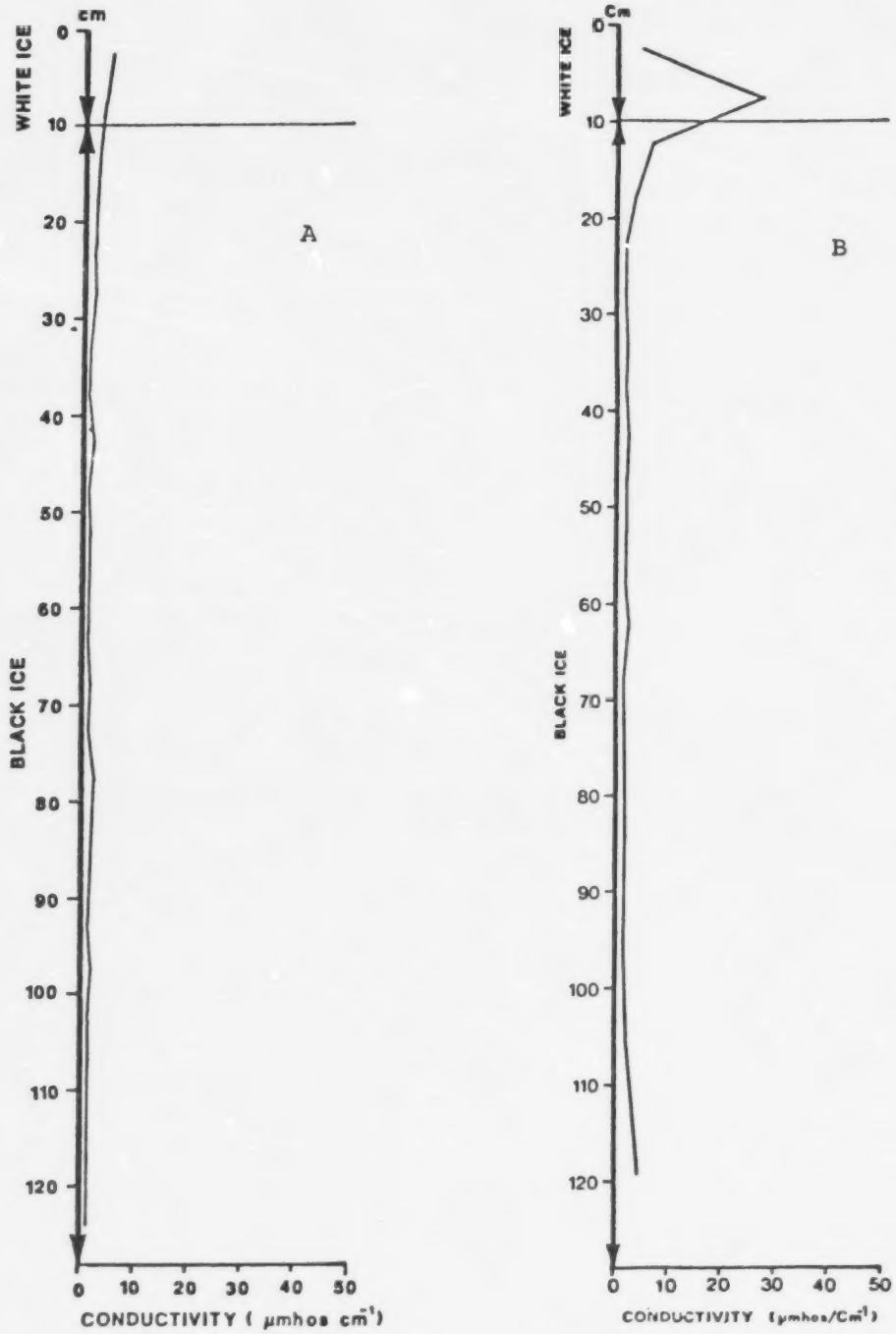


Figure 3. Conductivity profiles of ice blocks from Knob Lake deep hole (A) and site C (B), 11 May, 1985.

The specific ion results for Ca^{++} and Mg^{++} were compared to the results of two regression equations derived by T.R. Moore of McGill University (Moore, 1985). The equations are based on several samples of water from organic terrain in the Knob Lake watershed, under both acidic and alkaline conditions. Conductivity (umhos cm^{-1}) was used to predict $[Ca^{++}]$ and $[Mg^{++}]$. The equations are:

$$Ca = (0.081 \times \text{conductivity} + 0.59) \quad (1)$$

$$Mg = (0.058 \times \text{conductivity} + 0.30) \quad (2)$$

The dimensions of the ice and snow cover, and conductivity of the water column were measured at Knob Lake's deep hole and a near shore site (Fig. 2). Twice a week, at each site, a hole was drilled in the ice using a Snabb spoon drill (except when holes had not refrozen) and the dimensions of the lake cover, namely snow depth, black and white ice thickness, and hydrostatic water level, were measured using a metre stick and/or calibrated drill shaft. Samples were pumped from the water surface, 0.5 m depth, 1.0 m depth, and every metre beyond until the bottom was reached, using a peristaltic pump and graduated nalgene tubing. These samples were stored in pre-washed 125 ml nalgene bottles for later analysis of conductivity at 25°C.

A chemical mass balance was performed for the deep hole by first calculating mean conductivities for each one metre stratum, from stratum top and bottom values. Ice conductivities were calculated using values from the deep hole ice block, assuming melt was primarily restricted to the surface. Decreases in ice volume over time were balanced by increases in the volume of the second, water, stratum. Means were calculated for the whole lake, and top, bottom, and middle thirds of the lake's depth in order to determine where conductivity increases or decreases were occurring (ice was included in all surface calculations). The four means were then used in Moore's (1985) equations and multiplied by the respective volumes to predict Ca^{++} and Mg^{++} mass.

Results

Overall conductivity of the deep hole ice block is low, with a slight rise indicated in the white ice (Fig. 3A). However, the block taken from site C shows a markedly different distribution (Fig. 3B). This block displays a large conductivity peak in the white ice, which decreases quickly in the black ice to very low values.

Only the deep hole block could be analyzed for specific ions due to accidental contamination of the other samples. In the deep hole block, calcium was undetectable, magnesium was highest in the white ice but in very low concentrations throughout, and sodium and potassium both displayed peaks near the ice surface and a decrease in concentration towards the ice bottom (Fig. 4).

Figures 5 and 6 show conductivity changes at the two sites throughout break-up and after. In both cases conductivities near the ice/water interface during the first sampling were greater than 80 umhos cm^{-1} and as the melt began they became less than 10 umhos cm^{-1}. As the melt progressed, the conductivity gradient became less steep, indicating that the diluting effect of the melt was being felt progressively lower in the profile.

Before ice-free conditions, conductivity increased with depth to just over 90 umhos cm^{-1} at the near shore site, and greater than 150 umhos cm^{-1} at the deep hole. Once ice had left the lake, more or less uniform conductivities were found at all depths and the lake might be said to be "isoconductive". Conductivities stabilized at or around 80 umhos cm^{-1} for the summer.

Specific ion data for the water column only exist for late summer of the study year at site C (Fig. 7). At this point the lake was still isoconductive, at around 80 umhos cm^{-1}. Specific ion analysis showed that in Knob Lake, calcium is present at approximately 7 mg l^{-1}, magnesium at 4–5 mg l^{-1} and both sodium and potassium are present at levels less than 1 mg l^{-1}. This suggests that conductivity is controlled by Ca^{++} and Mg^{++}, presumably as the bicarbonates, which is a common observation in the watershed (Moore, 1985). In fact Moore's (1985) regression equations for Ca^{++} and Mg^{++} in the watershed, were found to be very accurate predictors of the two cations in the lake (Fig. 7).

When dividing the lake into three different strata conductivities were found to be substantially different in each stratum (Fig. 8). Conductivities were highest during the melt in the bottom third of the lake and lowest in the top third. At the beginning of the melt period all levels decreased in conductivity until June 3, at which point all levels increased until June 11 or June 14. At this time, conductivities moved towards an isoconductive state on June 21.

Magnesium and calcium mass for the whole lake, since based on conductivities, followed a similar pattern over time. However, the different levels of the lake responded differently to the melt, the top third decreased to June 3 and then generally increased until ice-free. The middle third and bottom third both decreased in Ca^{++} and Mg^{++} mass throughout the melt.

Discussion

The difference in ionic distribution of the two ice blocks extracted can best be explained by the process of white ice formation involved in each case. Since the study year was an unusually low snow year, it is reasonable to assume that little to no natural slushing by snow depression occurred. The low white ice conductivities suggest the latter.

Slushing from snow depression incorporates ion-enriched water originating from exsolution. This results in high ionic concentrations in the white ice upon refreezing (cf. Adams and Lasenby, 1985). The fact that the deep hole block showed only a small difference in white ice to black ice conductivities indicates that sub ice water was not involved in white ice formation, but instead white ice was formed by surface melt and/or precipitation. This suggestion is supported by the fact that after permanent ice was established there occurred two successive days with above 0°C temperatures.

The climatological record shows that on November 28 a maximum of 5°C was recorded as well as 1.2 mm of rain. The record for the following day shows a maximum of 5.4°C and minimum of just −0.2°C, with no precipitation. This represents a period of more than 24 hours of above zero temperatures which would seem sufficient to melt some or all of the lake snow cover and cause ponding on the ice surface. Upon refreezing the newly formed white ice would have low ionic strength.

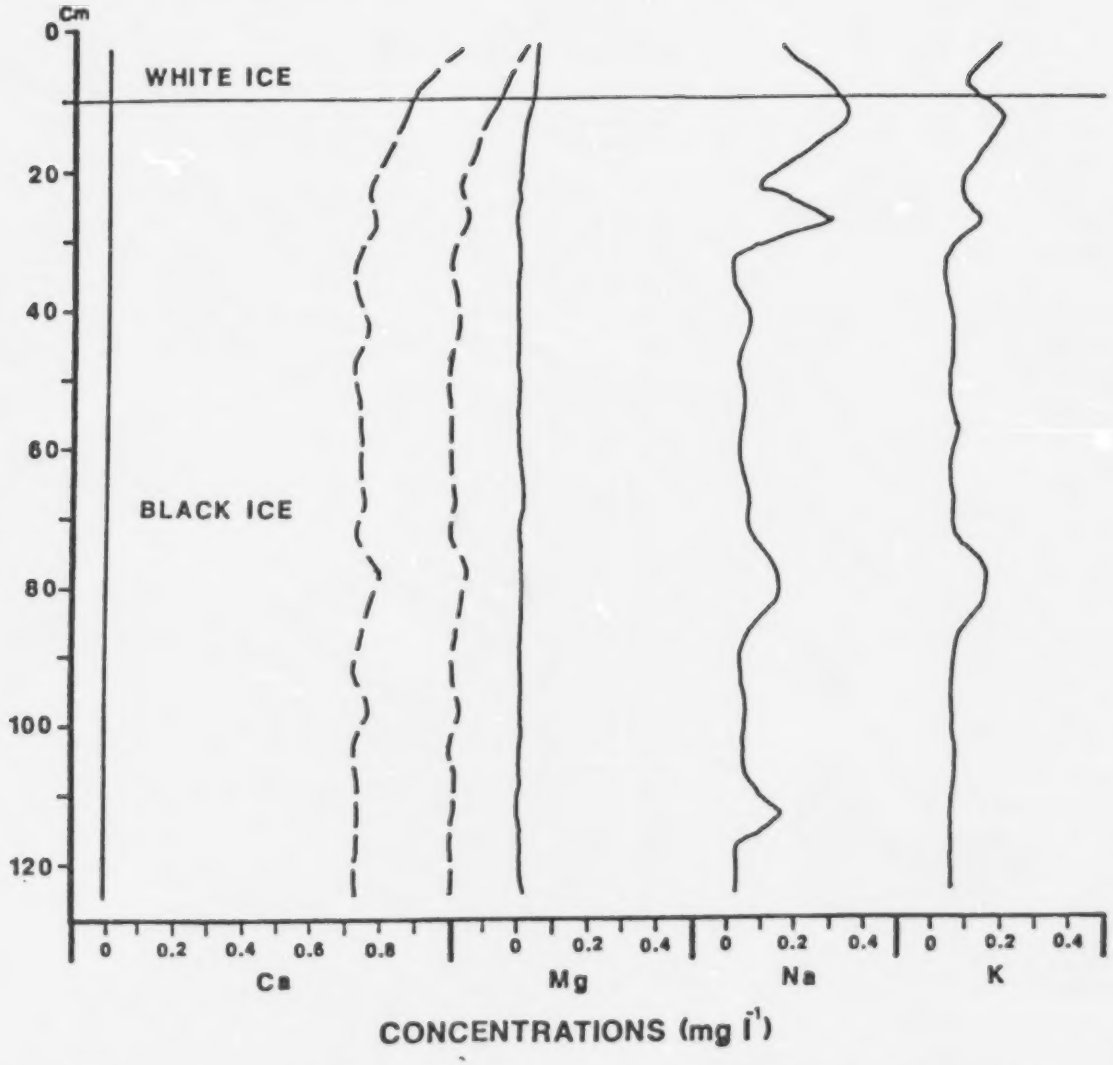


Figure 4. Major cation profile of ice block from Knob Lake deep hole site, May 11, 1985. Different lines are for actual values (_____), and predicted values (– – – –) using Moore's (1985) equations.

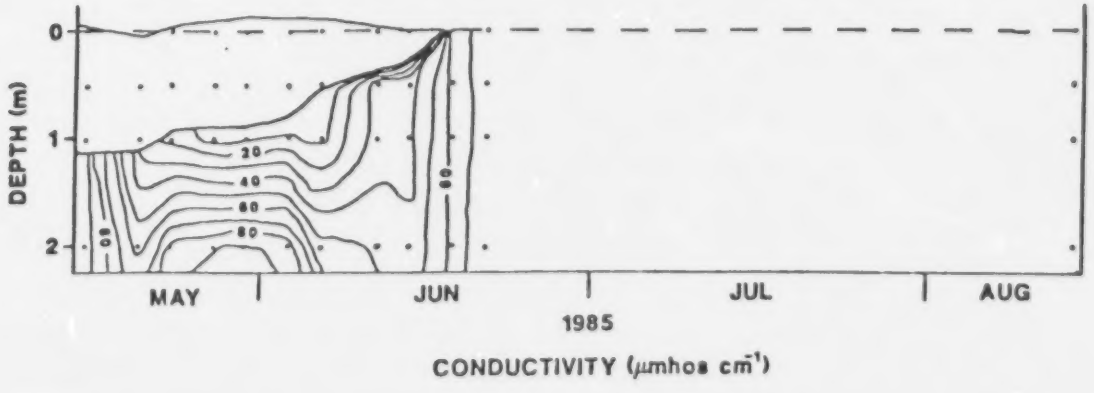


Figure 5. Knob Lake sub ice conductivity overtime at near shore site. Isoline interval = 10 umhos cm^{-1}.

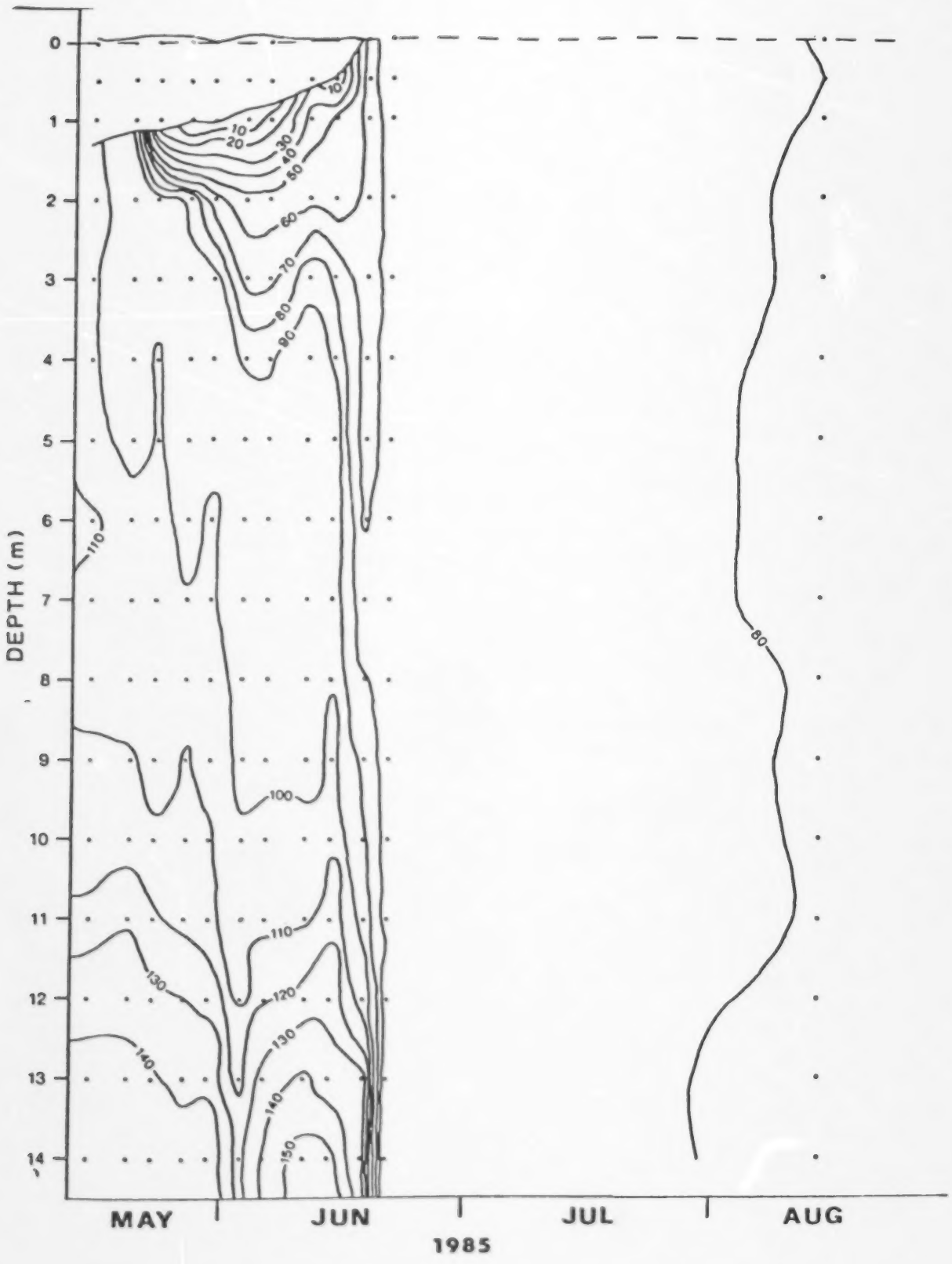


Figure 6. Knob Lake sub ice conductivity over time at deep hole site. Isoline interval = 10 umhos cm^{-1}.

The question of the second ice block with relatively high white ice conductivities can be explained by its location. This block was removed from the site of the regular ice survey where drilling takes place weekly (see Adams *et al.*, 1985). At more than one time during the winter hydrostatic water levels were positive, therefore any drilling would cause artifical slushing of the surface. This slushing would incorporate the ion rich waters of exsolution.

Specific ions in the ice blocks were very low as is to be expected with the low conductivities, however it is curious that Ca^{++} and Mg^{++} do not show dominance over Na^{+} and K^{+} as was found in Knob Lake's water column. Instead Ca^{++} and Mg^{++} were near or at null concentrations while $Na^{+}$and K^{+} were found at some levels in the black ice at greater than 0.2 mg l^{-1}. These differences in black ice concentration are consistent with the findings of Adams and Lasenby (1985) for the same lake. It appears that Ca^{++} and Mg^{++} are somehow more efficiently exsolved than Na^{+} and K^{+}. Shumskii (1964) explains that because variations occur in freezing conditions, the quantity and types of impurities excluded during exsolution will vary.

In the black ice it is interesting to note that concentrations of Na^{+} and K^{+} are greatest just below the white ice/black ice interface and generally decrease to a point around 35 cm. This likely reflects inefficient exsolution during the rapid freezing of early winter.

It appears that Moore's (1985) regression equations for Ca^{++} and Mg^{++} break down at low conductivities, such as are present in the ice blocks. For Mg^{++} the equation predicted negative concentrations for all but one reading, and for Ca^{++} predicted between 0.7 and 1.0 mg l^{-1} when none was detected. In Knob Lake, Adams and Lasenby (1985) detected black ice Ca^{++} concentrations of zero to approximately 0.2 mg l^{-1} in a block with conductivities in excess of 10 umhos cm^{-1}. Therefore it can be said that neither equation is functional at low conductivities. The appearance of the equations themselves suggests this. For instance, the Mg^{++} equation has a negative intercept, hence the negative concentrations at low conductivities. Perhaps the positive intercept in the Ca^{++} equation is responsible for overprediction of Ca^{++} at low conductivities. One might imagine, though, that under conditions of heavy white ice growth by slushing (normal for this area) these equations would be suitable for predicting white ice Ca^{++} and Mg^{++}.

The deep hole and near shore sites both showed similar response to the diluting effect of the melting ice. The dilution encroached lower into the water column as the melt proceeded. This indicates a downwelling of water presumably caused by temperature/density changes in response to the melt, which in turn increases sub ice circulation. This latter phenomenon is presently under investigation (Doran and Adams, in prep).

The higher benthic conductivities in the deep hole reflect the findings of Schindler *et al.* (1974) and Welch and Bergmann (1985) who supported the hypothesis that water adjacent to the bottom picks up heat from the sediments, becomes more dense, and hence sinks downward and slowly progresses downslope as it continues to warm. This process will also play a role in sub ice circulation.

Ideally, we would not expect the mass balance mean conductivity values or the whole lake Ca^{++} and Mg^{++} mass to change over time, because whole lake storage is assumed constant. Instead we would simply expect the chemical mass to shift from one stratum to another. This, however, is naive thought since the lake system beneath the ice is very much a dynamic one (cf. Likens and Hasler, 1962; Rahm, 1985). Therefore measurement at one site will not account for lateral movement of ions. Furthermore, during the melt several ionic

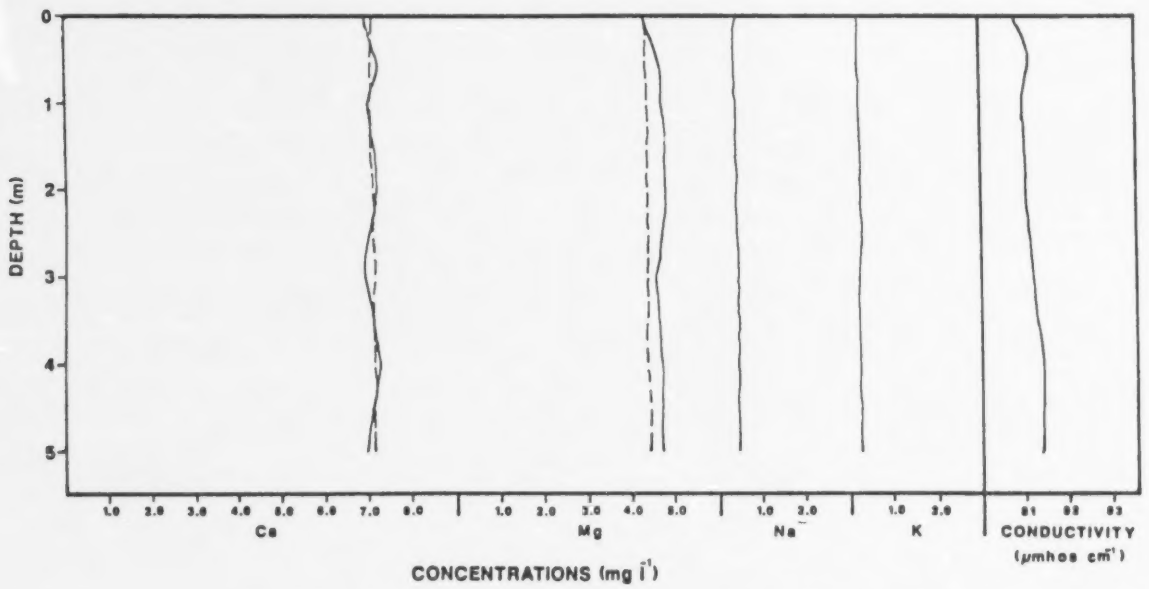


Figure 7. Major cation profile at Knob Lake, site C, 4 September, 1985. Different lines are for actual values (_____), and predicted values (– – – –) using Moore's (1985) equations.

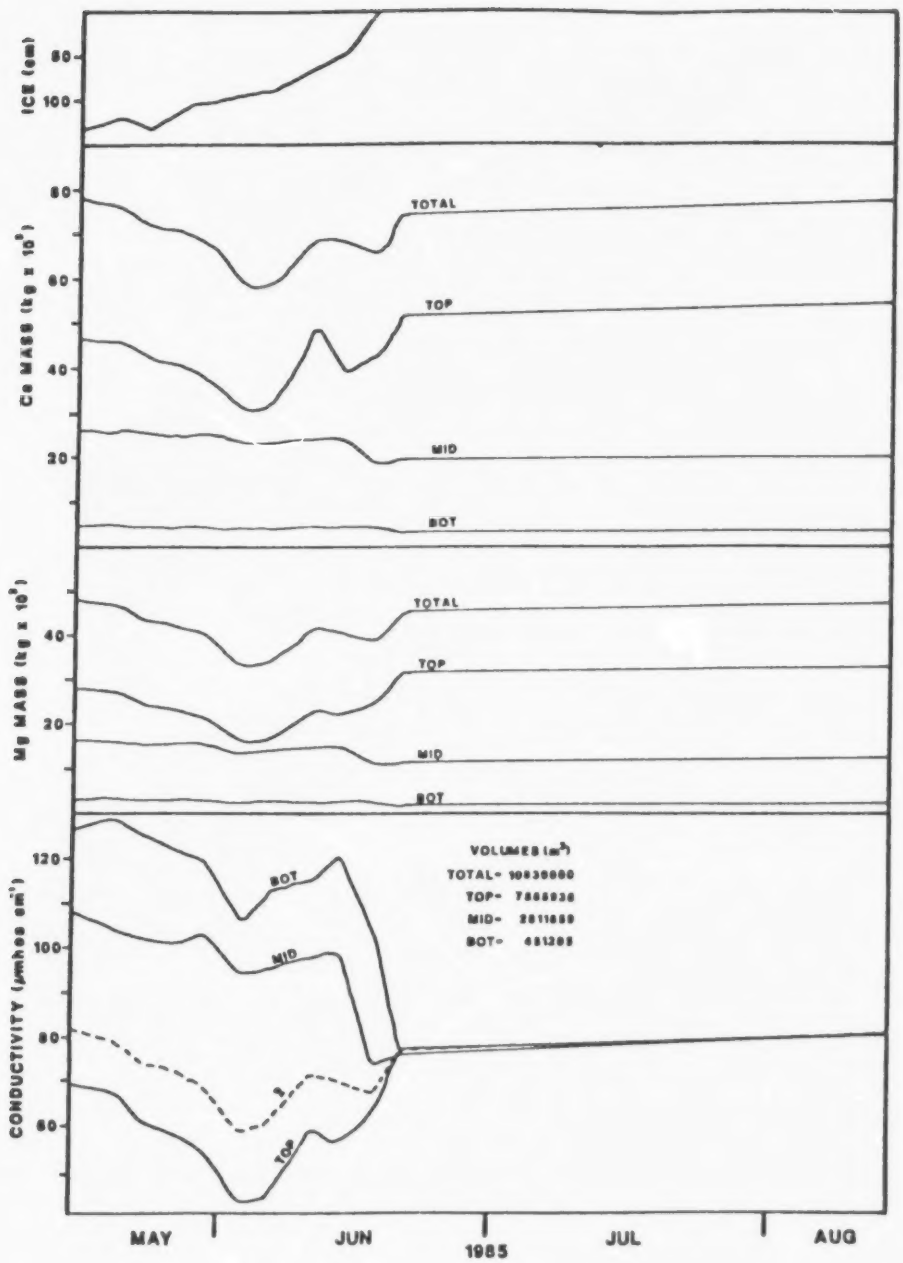


Figure 8. Knob Lake mean conductivity, and Ca^{++}, Mg^{++} mass for top, middle, bottom strata, and whole lake over the break-up period. Mass was calculated using Moore's (1985) equations.

imbalances will be occurring as a result of snow melt runoff, increased streamflow, etc. It is likely that snow melt runoff, in conjunction with ice cover melt, is responsible for the conductivity decrease at the beginning of the melt. Gunn and Keller (1985) noted a similar decrease in conductivity during the melt period, that continued after snowmelt runoff had ceased, indicating the important diluting role ice plays in the melt.

This role can be further identified by looking at the distribution of the ions in the lake basin at peak ice (May 15). At this time we find that the lake snowpack represents 1.58 $\times$ 10^4 m^3 water equivalent with an average conductivity of 5.2 umhos cm^{-1}, and the immediate lake basin snowpack represents 4.94 $\times$ 10^5 m^3 water equivalent with an average conductivity of 7.3 umhos cm^{-1}. On the other hand, the lake ice cover represents 2.22 $\times$ 10^6 m^3 water equivalent with an average conductivity of 2.2 umhos cm^{-1}, which incorporates a substantially greater potential for dilution. Waters from Knob Lake's major inflow ranged from between 53.5 and 64.0 umhos cm^{-1} during the study period, and therefore would have little diluting effect.

Conductivities and therefore Ca^{++} and Mg^{++} mass increased in the top layer, and decreased in the bottom and middle layers, after a certain point. The increase in the top layer is simply a function of the ice cover becoming minor, itself, volumetrically.

Conclusions

It must be kept in mind, when reviewing the results of this study, that the study year was not typical for this region. During this particular winter, well below average snowfall occurred, which was reflected by low white ice conductivities (except in areas of artificial slushing). Upon melting this ice would have a much greater diluting effect than in other years. Perhaps this is the best situation for observing dilution effects as they would tend to be amplified. Regardless, this is how the results should be viewed and not in the context of a typical year.

The findings of the study are summarized:

1) Ca^{++} and Mg^{++} appear to be more efficiently exsolved than Na^{+} and K^{+}.
2) Moore's (1985) equations for predicting Ca^{++} and Mg^{++} from conductivities in Knob Lake watershed do not function well at the low conductivities found in ice blocks. However, they work well for the higher conductivities of the Knob Lake water column.
3) Dilution encroaches lower into the water column as the melt proceeds, indicating a density-induced downwelling. Furthermore benthic conductivities were greater at the deep hole than at the shallow site suggesting a downslope migration of solute rich waters. Both of these phenomena would play a role in sub ice circulation.
4) Whole lake conductivity and Ca^{++} and Mg^{++} mass decrease for the first half of the melt and then increase until the lake is isothermal. Although snow melt must play a role in the initial dilution, ice cover seems to be the dominant factor. The increase in the second half is believed a function of the ice cover becoming minor, itself, volumentrically.

Acknowledgments

I gratefully acknowledge funding supplied by a Department of Indian and Northern Affairs, Northern Scientific Training Grant. W. Peter Adams supervised the project and provided a large amount of support and encouragement throughout. Craig Allan provided much insight and advice. Several people aided in data collection including Oksana Choulik, Barry McArthur, Ralph Shaw, Andy Westcott, and Chris Kingsbury. To them I am also indebted. The McGill Subarctic Research Station has provided an invaluable service to myself and many others over the years. I am particularly grateful for the loan of several pieces of equipment.

References

Adams, W.P. 1982. A Quarter Century of Northern Research. Musk-Ox 30:74-80.

Adams, W.P., Barr, D.R., and Jackson, P. 1985. Archives of the ice record from Knob Lake, Quebec 1954 - present. Proceedings of the Eastern Snow Conference., (in press).

Adams, W.P. and Lasenby, D.C. 1985. The roles of snow, lake ice and lake water in the distribution of major ions in the ice cover of a lake. Annals of Glaciology 7:202-208.

Barica, J. and Armstrong, F.A.J. 1971. Contribution by snow to the nutrient budget of some small northwest Ontario lakes. Limnology and Oceanography 16(6):891-899.

Bryan, M.L. 1964. The morphology and morphometry of lakes in the Schefferville, Quebec area. McGill Subarctic Research Papers 22:154-182.

Doran, P.T. and Adams, W.P. in prep. Observations on water temperature anomalies during subarctic lake ice decay.

Drake, J.J. 1981. Summer water chemistry in two subarctic watersheds. McGill Subarctic Research Papers 32:73-83.

Findlay, B.F. 1966. The water budget of the Knob lake area. McGill Subarctic Research Papers 22:1-95.

Gorman, E., Bayle, S.E., and Schindler, D.W. 1984. Ecological effects of acid deposition upon peatlands: A neglected field in 'Acid Rain' research. Canadian Journal of Fisheries and Aquatic Science 41:1256-1268.

Gunn, J.M. and Keller, W. 1985. Effects of ice and snow cover on the chemistry of nearshore water during spring melt. Annals of Glaciology 7:208-212.

Kingsbury, C.M. 1983. Cryochemistry of the decaying winter cover of a temperate pond. Special N.S.E.R.C. Summer Assistant Report, Department of Geography, Trent University, Peterborough, Ontario.

Likens, G.E. and Hasler, A.D. 1962. Movements of radiosodium (Na24) within an ice-covered lake. Limnology and Oceanography 7:48-56.

Moore, T.R. 1985. Communication to W.P. Adams.

Rahm, L. 1985. The thermally forced circulation in a small, ice-covered lake. Limnology and Oceanography 30(5):1127-1128.

Schindler, D.W., Welch, H.E., Kalff, J., Brunskill, G.J., and Kritsch, N. 1974. Physical and Chemistry Limnology of Char Lake, Cornwallis Island (75° N lat.). Journal of the Fisheries Research Board of Canada 31:585-607.

Shumskii, P.A. 1964. Principals of Structural Glaciology. The petrograph of freshwater ice as a method of glaciological investigation (Translated by D. Kraus). Dover Publishers Incorporated, New York, New York.

Welch, H.E. and Bergmann, M.A. 1985. Water circulation in small arctic lakes in winter, Canadian Journal of Fisheries and Aquatic Science 42:506-520.

LA PARTIE NORD DE LA FOSSE DU LABRADOR: ZONE DE CHEVAUCHEMENT MAJEURE?

Francis Falardeau

Géologie structurale, Université du Québec à Montréal, Montréal, Québec H3C 3P8

Niveau: Maîtrise

Résumé

Une étude récente dans la partie nord de la fosse du Labrador aux environs de la Baie aux Feuilles met en évidence une série d'imbrications d'unités stratigraphiques plus vieilles, hautement métamorphisées, sur des unités mobiles plus jeunes, d'âge Aphébien, peu à très métamorphisées issue de l'érosion des premières. Trois épisodes de déformation de l'orogène Hudsonien (1750 Ma) ont été observées dans les séquences sédimentaires et volcaniques Protérozoiques. La région de la Baie aux Feuilles est particulièrement bien exposée pour permettre d'observer des failles majeures associées à des failles secondaires syntectiques. De minces niveaux pseudotachylitiques ont été observés dans les zones de dédoublement de la croûte terrestre. Le système de contraintes compressionnel orienté est — ouest est orthogonal par rapport à celui de Cape Smith situé à 400 Km plus au nord. L'orientation de l'étude est à caractère métallogénique régional: Les études structurales subséquentes serviront à établir un modèle de base pour le positionnement stratigraphique et structural de gisements éventuels de platinoides, or, et autres métaux de base tels que Cu, Pb, Zn.

Mots-clés: Failles, pseudotachylite, Fosse du Labrador, Ungava.

Abstract

The recent discovery of rocks containing pseudotachylites in the vicinity of the Baie aux Feuilles, in the western part of Ungava Bay, suggests that the geological assemblages in this sector underwent significant shifts along the planes of major faultlines some 1700 million years ago. The pseudotachylites are the result of intense shearing stresses associated with the formation of the Labrador Trough and the partial fusion of the surrounding rocks. These zones could be important as targets for mineral prospecting (including prospecting for gold and platinum).

Key words: Faults; pseudotachylite; Labrador Trough; Ungava.

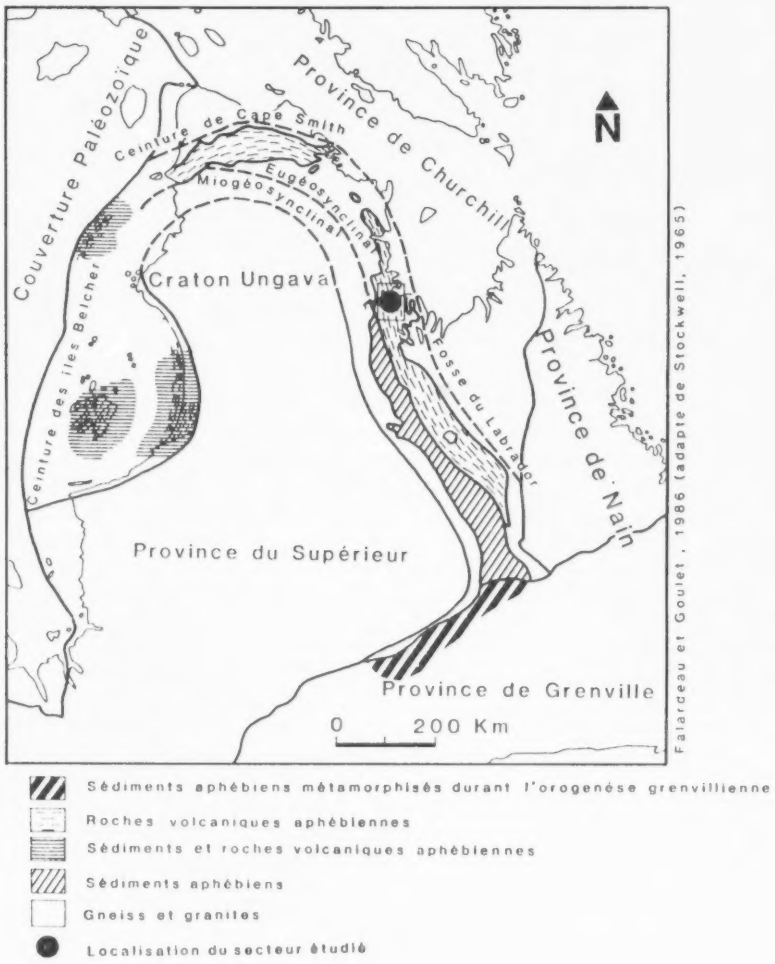
Introduction

Une cartographie géologique détaillée dans la région nord-ouest de Kuujjuaq (Fig. 1) ayant comme limites naturelles la Baie aux Feuilles au nord, un socle archéen à l'ouest et à l'est, a débuté à l'été 1984. Les roches aphébiennes de la Fosse du Labrador ont subit un tectonisme polyphasé lors de trois épisodes de la collision orogénique Hudsonienne vers 1735 ma. Cette collision semble correspondre à la fermeture d'un rift actif au Protérozoique inférieur au cours duquel se sont déposés d'épaisses séquences volcano-sédimentaires. Une quatrième déformation tardive est responsable de la crénulation observée dans la zone nord-est près du socle archéen. Un polymétamorphisme est également présent dans la Fosse du Labrador avec une intensité croissante du métamorphisme vers sa bordure est. L'orientation des plis P1 est essentiellement nord-sud avec un style de plissement isoclinal. Le plissement P2 a repris le premier avec une orientation nord-sud à nord-ouest/sud-est. Enfin, une troisième phase de plissement P3 a reprit les deux précédantes. Des failles directionnelles majeures parallèles aux plis P1 mettent en évidence un système de cisaillement à composante horizontale. Des plis syntectiques semblent associés à ces zones de failles. On retrouve dans ces zones des veines pseudotachylitiques discontinues qui correspondent à une fracturation-fusion de la roche à la suite d'une déformation intense en zone restreinte. On devrait rattacher ces veines à un métamorphisme régional plutôt que local. Il s'agit d'une dissipation mécanique de la chaleur. Les veines parallèles à la schistosité sont millimétriques; alors que celles qui sont obliques sont parfois décimétriques. Les pseudotachylites sont intimement liées à des zones mylonitiques («chaudes et mouillées») et parfois cataclastiques («froides et sèches»); mais semblent être syn à post-génétiques puisqu'elles sont tantôt parallèles à des zones de brèches tectoniques; tantôt recoupant toutes les unités. Les pseudotachylites ont été observées dans plusieurs types de roches. Elles s'infiltrent dans la schistosité de conglomérats hautement mylonitisés, dans les grès, les métadolomies, les volcaniques, et même les dômes de gneiss archéen orientaux. Les pseudotachylites adoptent une forme sporadique de sorte que ces unités sont difficiles à suivre. On a retrouvé néanmoins, à 40 Km plus au nord, au nord-ouest de Aupaluk (Ikattok bay) au même niveau stratigraphique un horizon de pseudotachylites. Ce qui semble confirmer la présence d'une zone de failles majeures de chevauchement sur toute la partie est de la Fosse du Labrador; plutôt qu'un fait géologique locale. Des textures sigmoidales caractéristiques dans les zones conglomératiques à cailloux étirés suggèrent des mouvements horizontaux importants associés aux mouvements verticaux de chevauchements. L'axe long des cailloux avait une orientation moyenne de 08575. Ce niveau repere conglomératique possède une épaisseur stratigraphique de 20 à 300 m et se trouve à la base d'une épaisse séquence de coulées volcaniques qui pourrait être l'équivalent distal de la formation d'Hellancourt. Des plutons gabbroiques recoupent le tout.

Géologie économique

Des indices de Platines ont été observés à la base de gabbros porphyriques situés dans la partie sud-est de la région étudiée. De nombreux horizons repères à sulfures, dont certains sont constitués essentiellement de pyrite massive ou stratiforme, suggère une genèse exalative. Une remobilisation des sulfures massifs par les fluides hydrothermaux injectés dans la schistosité et les zones de cisaillement lors des différents épisodes orogéniques hudsoniens complexifie la cible d'exploration pour d'éventuels gisement de Au, Pt, Zn, Cu.

Carte de localisation dans le circum-Ungava



Les métadolomies possèdent une porosité primaire et secondaire suffisante pour constituer une métallotecte de Pb-Zn syn-sédimentaire.

Métamorphisme

En bordure est de la Fosse du Labrador des minéraux métamorphiques caractéristiques se sont développés et définissent des isogrades de métamorphisme croissant de l'ouest vers l'est: Chlorite (P = 0−4 Kbar; T = 200−500 C), biotite (P >= 4 Kbar; T = 300−650 C), actinote, grenat almandin (P >= 4 Kbar), staurotite (P = 4−7 Kbar; T = 540−565 +/− 15 C), Dysthène (P >= 8 Kbar), Sillimanite (P >= 6 Kbar).

Géochronologie

Une datation U-Pb sur zircon d'une granodiorite du socle archéen ouest à la hauteur de Leaf Bay a donné un âge de formation de 2721 +5/−3 ma (Machado, 1986). Trois dômes de gneiss replissés en même que la Fosse du Labrador situés à l'est de celle-ci ont donnés des âges comparables: Le dôme du lac Olmstead a donné un âge U-Pb sur zircon de 2721 +4 ma correspondant à l'âge de formation. Une datation similaire sur sphène titanifère a donné un âge de métamorphisme de 1768 +14 ma. Le dôme du lac Boulder a donné un âge de formation U-Pb sur zircon de 2874 +5 ma et un âge métamorphique sur sphène de 1782 +11 ma. Enfin le dôme du lac Moyer a donné un âge de formation sur zircon de 2882 +4 ma et un âge métamorphique sur monazite de 1774 +4 ma. De plus ces études isotopiques font ressortir les événements géologiques suivants:

1) 2880− 2720 ma: âge de déposition initiale et terminale des séquences dans la Fosse du Labrador.

2) 1769 +10/−15 ma: meilleur âge de métamorphisme correspondant à l'orogenèse Hudsonienne.

3) 1745 ma: activité hydrothermale intense.

Géophysique

Des études gravimétriques préliminaires de grande profondeur ont été générées pour observer un éventuel épaississement de la croûte dû au chevauchement et afin de complémenter les études structurales. Des études gravimétriques et magnétotéluriques sont prévus au programme l'année prochaine.

UNDERWATER CAMERA SYSTEM USED IN PANGNIRTUNG FIORD, BAFFIN ISLAND

John Glew

Department of Geography, Queen's University, Kingston, Ontario K7L 3N6

Level: Ph.D.

Abstract

During the last ten years, members of the Department of Geography at Queen's University have been engaged in research dealing with various aspects of arctic fiord sedimentation, (Gilbert 1978, 1982, 1983). In the last two years some of this work has been directed specifically towards the subtidal environment of Pangnirtung Fiord in Baffin Island (66°50′W. 66°10′N). Knowledge of this subtidal environment had been obtained through such techniques as seismic and echo profiling and by grab and box core sampling, the latter being the only method that enables one to examine the bottom surface directly. The need to view the undisturbed bottom conditions of the fiord over a wide area is important, particularly in the assessment of both the benthos, and the character of the sediments.

The use of bottom triggered underwater cameras in oceanographic work has been a routine procedure for many years, and a number of excellent camera systems are available. However, the decision to design and build this system was due to the unavailability of commercial units for our specific operation. Generally, off-the-shelf camera systems fall into one of two categories: (1) lightweight units, designed for shallow water hand-held use, (2) heavy oceanographic systems designed for deep water work supported by a large ship. The first category is unsuitable because the cameras are not remote operating and have depth limitations, those in the second category are over-engineered for shallow marine work; as well they are cumbersome and expensive.

The design of the Queen's unit resulted in a system that incorporated a standard, unmodified 35 mm S.L.R. camera and flash housed within a simple watertight case that is small, light and robust enough to be used from an open boat operating in a marine environment, to depths of several hundred metres. Use of the system over the last two field seasons has resulted in the recovery of a large number of bottom photographs. For the purposes of the Pangnirtung study all the photographs were vertical, and taken from a height of 1.5 metres above the bottom. Each covers an area approximately 1.0 × 1.5 metres. They are presently being used to compile a more complete inventory of fauna and flora in the fiord, and to compare the range of physical environments in the subtidal region.

Key words: Pangnirtung, N.W.T., camera, automatic, underwater.

Résumé

Au cours des dix dernières années, les membres du département de géographie de l'Université Queen's ont accompli des recherches sur les divers aspects de la sédimentation dans les fiords arctiques (Gilbert 1978, 1982, 1985). Certains travaux accomplis au cours des deux dernières années ont porté en particulier sur la zone infralittorale du fiord Pangnirtung, dans l'île de Baffin (66°50′0., 66°10′N).

L'auteur a recueilli des données sur cette zone infralittorale par des techniques de prospection sismique et d'échosondage, et par l'échantillonnage au fond et celui de carottes de sondage. Ce dernier moyen constitue la seule méthode d'examen direct de la nature du fond du fiord. Il est important d'examiner ce fond non perturbé sur une grande superficie, particulièrement quand on étudie le benthos et la nature des sédiments.

Les appareils photographiques sous-marins à déclenchement automatique ont été utilisés depuis de nombreuses années pour les recherches océanographiques, et un certain nombre d'excellents appareils sont disponibles. Cependant, l'auteur a dû concevoir et construire son propre appareil photographique en raison de l'absence dans le commerce d'appareil convenant aux besoins particuliers de son travail. On divise en général les appareils photographiques spécialisés du commerce en deux catégories: 1) les appareils légers conçus pour les eaux peu profondes et tenus à la main, et 2) les appareils océanographiques, lourds et conçus pour les travaux en eau profonde, avec le soutien d'un navire. Les appareils de la première catégorie ne convenaient pas, parce qu'ils ne peuvent être télécommandés ni fonctionner en eau profonde; ceux de la seconde sont trop perfectionnés pour le travail en eau peu profonde et, ils sont encombrants et coûteux.

La conception de l'appareil de photographies sur film de 35 mm du département de géographie a permis de lui incorporer un système réflex à un seul objectif et une lampe-éclair, et de loger le tout dans un compartiment étanche de petite taille, léger et assez robuste pour utilisation à plusieurs centaines de mètres de profondeur, à partir d'une embarcation non pontée. Au cours des deux dernières saisons de travail, cet appareil a permis de prendre un grand nombre de photographies du fond du fiord. Pour les fins de l'étude, toutes les photographies sont prises verticalement, d'une hauteur de 1,5 m au-dessus du fond, et chacune couvre une superficie d'environ 1 m par 1,5 m. Elles permettent d'effectuer actuellement un inventaire plus détaillé de la faune et de la flore du fiord et de comparer la série d'environnements physiques de la zone infralittorale.

Mots-clés: Fiord de Pangnirtung, île de Baffin, T.N.-O. appareil photographique, zone infralittorale.

Introduction

During the last ten years, members of the Department of Geography at Queen's University have been engaged in research dealing with various aspects of arctic fiord sedimentation, (Gilbert 1978, 1982, 1985). In the last two years some of this work has been directed specifically towards the subtidal environment of Pangnirtung Fiord in Baffin Island, (66° 50′ W, 66° 10′N).

Knowledge of this subtidal environment had been obtained through such techniques as seismic and echo profiling, and by grab and box core sampling, the latter being the only method that enables one to examine the bottom surface directly. The need to view the undisturbed bottom conditions of the fiord over a wide area is important, particularly in the assessment of both the benthos, and the character of the sediments.

The use of bottom triggered underwater cameras in oceanographic work has been a routine procedure for many years, and a number of excellent camera systems are available. However, the decision to design and build this system was due to the unavailability of commercial units for our specific operation. Generally, off-the-shelf camera systems fall into one of two categories: (1) lightweight units, designed for shallow water and hand-held use, (2) heavy oceanographic systems, designed for deep water work supported by a large ship. The first category is unsuitable for the Queen's work because the cameras are not remote operating and have depth limitations; those in the second category are over engineered for shallow marine work and they are cumbersome and expensive. Because of the difficulty in controlling instruments in deep water, automatic operation, as well as small size, is an important characteristic.

Instruments that are light weight and small have obvious advantages in that they may be transported and deployed from small boats. Such advantages may be diminished, however, when handling below the water surface, due to their small submerged weight. The camera unit weights approximately 6 kg when immersed. Under normal operating conditions, the ability to determine the behaviour of such a small light instrument on the end of a cable is indirectly proportional to the depth of water in which it is deployed. For example, the effect of waves, drift and the dynamic motion of the cable remove almost all 'feel' from the camera below a depth of 150 metres, and this is reduced even more when deployment is from boats that are themselves subject to waves, wind and current. For these reasons the camera unit described here is designed to operate automatically after it is placed in the water.

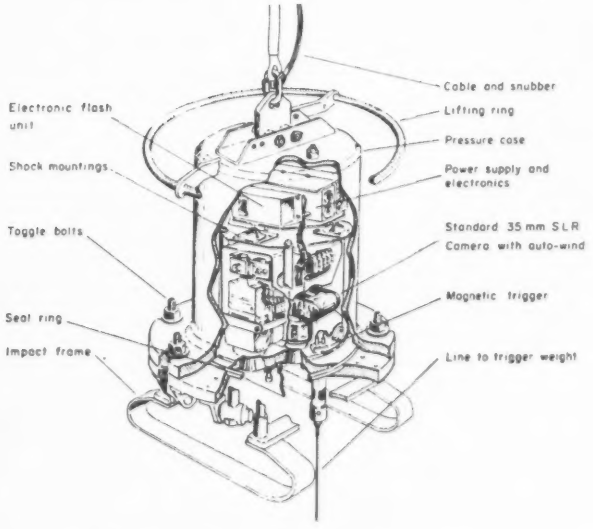


Figure 1. The underwater camera system.

General description

The design of the Queen's unit resulted in a system that incorporated a standard, unmodified, 35 mm S.L.R. camera and flash unit housed within a simple watertight case that is small, light, and robust enough to be used from an open boat operating in a marine environment to depths of several hundred metres. Use of the system over the last two field seasons has resulted in the recovery of a large number of photographs. For the purposes of the Pangnirtung study, all the photographs were vertical, and taken from a height of 1.5 metres above the bottom. Each covers an area approximately 1.0 × 1.5 metres. These photographs are presently being used to compile a more complete inventory of fauna and flora in the fiord, and to compare the range of physical environments in the subtidal region.

The camera unit consists of a two piece, watertight, case into which is mounted a shock-absorbing frame that supports both camera and flash unit, these face forward through separate ports in the front of the pressure case. The electronics and battery supply are located behind the camera and flash unit; space is provided for an extended film magazine with a capacity of 30 metres of 35 mm film (800 exposures). The unit normally operates on a neutrally buoyant polypropylene line, 1 cm in diameter, with a snubbing device inserted between the unit and the line to reduce shock loads on the instrument while being towed.

The unit can be operated in two separate automatic modes: a survey mode that enables photographs to be taken on contact with the bottom, and a time lapse mode used when taking repetitive photographs from a fixed location. The selection of either operational mode is made by a mode selection switch inside the case.

When in the survey mode, the camera is operated by an external trigger in the form of a weight suspended below the main camera housing. On contact with the bed the trigger closes the camera firing circuit to take a single photograph. In the time lapse mode the camera is controlled by an internal clock and may be left unattended on the bed for periods of up to ten days.

Survey mode operation

In the survey mode, the camera unit is dropped over the selected site and allowed to free fall through the water without cable restraint, after initial descent the unit need only be raised sufficiently to clear intervening topography between sites to be photographed. Under calm water conditions, in depths up to 150 metres, an echo sounder is useful when moving the camera as it can 'see' the camera in relation to the bottom; this is advantageous although not essential. Automatic operation in the survey mode consists of regulating the camera system in such a way that only one frame is exposed on each bottom contact. To ensure this single exposure, a disabling function is built into the control system that prevents the trigger circuit from operating for a pre-set period (30–150 seconds) after each photograph is taken. This electrically isolates the camera and the flash at the time the unit hits the bottom and is subject to mechanical shock.

Time lapse operation

Operation in the time lapse mode consists of replacing the external trigger with two timing circuits that operate the flash and the camera functions at predetermined intervals. The interval can be set from 5 minutes to 48 hours between consecutive exposures for up to a total duration of ten days.

For the time lapse operation the camera unit is bolted to a large sub frame that supports it in a vertical position 1.5 to 2.0 metres above the bed. In the time lapse mode the external trigger can, if required, be used to automatically reset the timing function or to turn the system off and on. In this way the whole assembly can be moved on location, or moved from one location to another and activated only on deployment.

References

Gilbert, R. 1978. Observations on Oceanography and Sedimentation at Pangnirtung Fiord, Baffin Island. Maritime Sediments. Vol. 14, No. 1, pp. 1-9.

Gilbert, R. 1982. Contemporary Sedimentary Environments on Baffin Island, N.W.T., Canada: Glaciomarine Processes in Fiords of Eastern Cumberland Peninsula. Arctic and Alpine Res. Vol. 14, No. 1, pp. 1-12.

Gilbert, R. 1985. Quaternary Glaciomarine Sedimentation Interpreted from Seismic Surveys of Fiords on Baffin Island, N.W.T. Arctic. Vol. 38, No. 4, pp. 271-280.

TOPOGRAPHIC CHANGE OF THE MEIGHEN ICE CAP, MEIGHEN ISLAND, N.W.T.

Thomas Westby Haythornthwaite

Department of Geography, Carleton University, Ottawa, Ontario K1S 5B6

Level: Master's

Abstract

The results of a levelling survey conducted in 1985 across the Meighen Ice Cap, Queen Elizabeth Islands, are compared to data from a 1960 survey. While most of the surface of this stagnant ice cap has been substantially lowered over the 25 year study period, the highest parts have increased in elevation. Stagnant ice caps do not flow and so can only change shape by variations in accumulation (mainly in the form of snowfall) and ablation (consisting mainly of meltwater run off). Differential ablation appears to be causing the ice cap's slopes to steepen and its margins to retreat. If the current situation continues, the ice cap may steepen to the point where ice flow begins. However, core analysis indicates that the ice has never flowed. Therefore it is probable that other factors (which may have operated in the past as well) will counter the current trends. As this research shows, stagnant ice caps do not maintain constant dimensions. Instead they may undergo reversals between advancing and retreating behaviour even when climate appears to be constant.

Key words: Topography, ablation, accumulation, High Arctic, Meighen, stagnant, ice cap, mass balance, glacier.

Résumé

L'auteur compare les résultats d'un levé topographique réalisé en 1985 sur la calotte glaciaire de Meighen, dans des îles de la Reine-Elizabeth, avec ceux de 1960. Bien que cette calotte soit stationnaire, sa surface a presque partout baissé notablement au cours de ce quart de siècle, mais ses points les plus élevés ont pris de l'altitude. Les calottes glaciaires stationnaires n'avancent pas, et leurs formes ne peuvent changer que par des variations de l'accumulation (surtout par des chutes de neige) et de la déperdition (surtout par ruissellement des eaux de fusion). Il semble que des différences de déperditions raidissent les pentes de la calotte glaciaire, et en grignotent le pourtour. Si les conditions actuelles persistent, ce pourtour peut devenir si escarpé que la glace commencera sa reptation. Cependant, l'analyse des carottes de sondage indique que la glace ne l'a jamais fait. Il est donc probable que d'autres facteurs (qui auraient pu agir également dans le passé) contrebalanceront les tendances actuelles. Comme l'auteur conclut, les calottes glaciaires stationnaires ne conservent pas des dimensions constantes. Celles-ci peuvent subir des alternatives de progression et de régression, même si le climat paraît constant.

Mots-clés: Topographie, déperdition, accumulation, Extrême-Arctique, Meighen, stationnaire, calotte glaciaire, équilibre massique, glacier.

Introduction

This paper illustrates the relative advantages of survey levelling over stake measurements for climatic monitoring of stagnant ice caps. The case of the Meighen Ice Cap, which has been monitored by both methods, is discussed.

Dynamic ice caps and glaciers (which are those ice masses whose ice thickness, bed steepness, and/or relatively warm conditions allow internal stress to exceed ice strength) adapt to local changes in mass balance by changing the rate at which the ice moves. Stagnant ice caps (which are too thin, and/or cold for ice motion) only react by changing their surface elevation. Stagnant ice caps respond immediately to climate change because there is no time lag effect caused by ice motion. Surface elevation at all points is only controlled by the local mass balance, or relative magnitude of accumulation and ablation. Mass balance is expressed in terms of units of mass of ice added or removed per unit area over a period of time (usually an integral number of years). Where a greater mass of ice per unit area is added than is removed, the mass balance is positive and the surface elevation is increased. Topographic changes, therefore, reflect an integration of net mass balance and may be monitored to provide climatic data

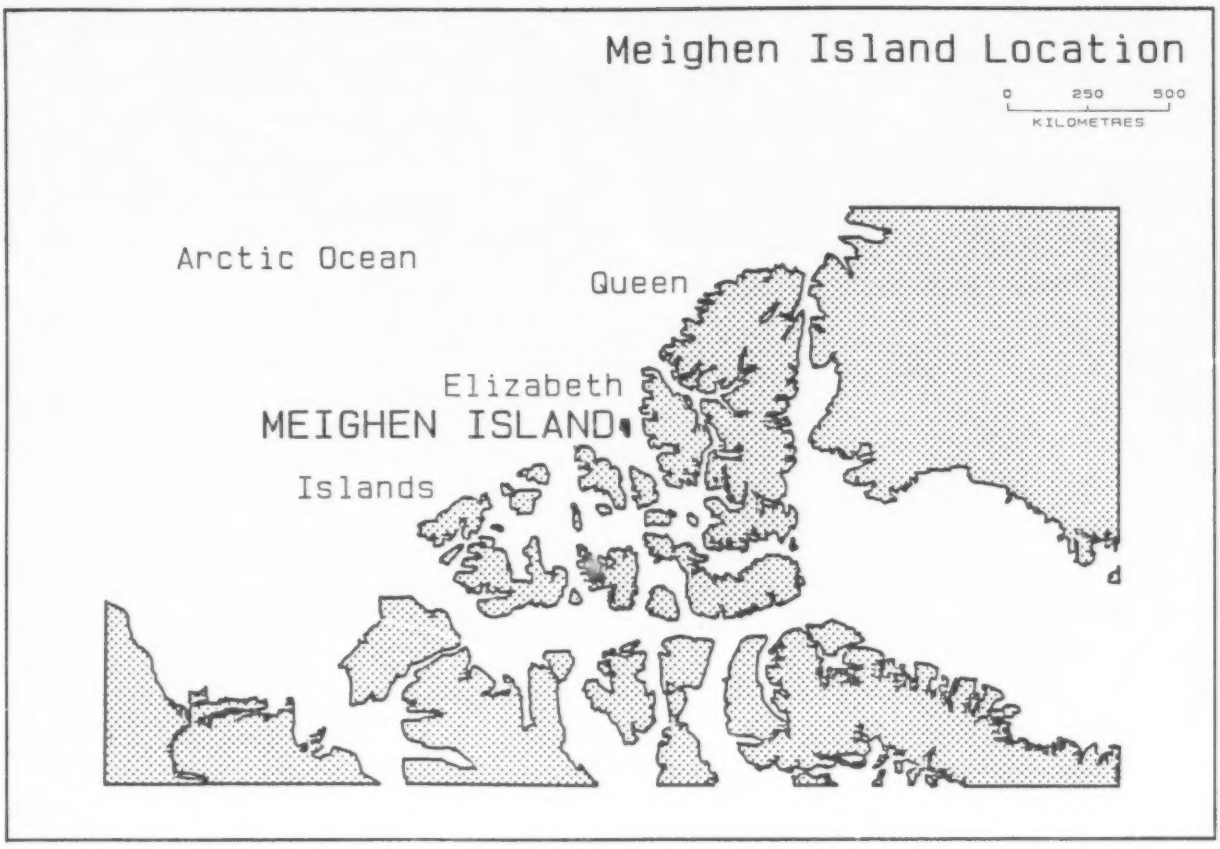


Figure 1. Meighen Island.

representing a combination of precipitation and temperature that may be useful for establishing climatic trends and for calibration of bore hole data or ice sheet modelling parameters.

Meighen Ice Cap

The Glacier Physics section of the Terrain Sciences division of the Geological Survey of Canada currently monitors the Meighen and Melville South Ice Caps (as well as dynamic ice caps and glaciers) in the high arctic using an annual mass balance observation method involving measurement of surface elevations relative to the tops of stakes or mass balance poles. The Meighen Ice Cap, on Meighen Island, (Figures 1 and 2) was measured in most of the past 26 years in this manner. In 1985, a levelling survey was also conducted to allow direct measurement of the net mass balance for the previous 25 years by comparison with a profile derived from 1960 surveys (Arnold, 1966).

The levelling method only provides a measure of climatic change if profiles derived from two surveys separated by an appropriate length of time can be compared. In the case of the Meighen survey, maps based on surveys and photogrammetry from 1960 provide a good means of comparison. As stake measurements are available for most intervening years, the ice cap provides the best available test site for the levelling method.

It is essential for this type of mass balance study that the ice cap be known to be stagnant. On Meighen, this has been shown conclusively by examination of a core drilled in 1965. The ice showed no evidence of ever having been strained, and it was concluded that the ice had never flowed (Koerner, 1968; Koerner and Paterson, 1974; Paterson, 1968; Paterson 1969).

The goal of the actual survey is to measure elevations at a large number of points at precisely known locations for comparison with the elevations at the same locations from another point in time. In practice it is best to survey many points along a straight line so that the elevation anywhere on the line may be interpolated from the surveyed points. The spacing of the points and the accuracy with which their location is determined must be great enough for the probable error anywhere on the profile to be substantially less than the topographic changes that are likely to have occurred. Given the surface roughness and expected closure errors, it was estimated that a maximum datum spacing of about 100 m ought to provide a profile with a greatest probable vertical uncertainty at any point of about 20 cm.

On Meighen, a line was selected that joined two of the permanent horizontal control monuments that were placed beside the ice cap about 1960. Given suitable conditions and sufficient resources, the best method of directing the survey along the correct line would be to aim a theodolite from one end towards the other, and to have an assistant use it (with vertical adjustment as required) to direct the levelling party 'left or right' by radio. For the levelling of the Meighen ice cap, constraints were provided by personnel, the overall

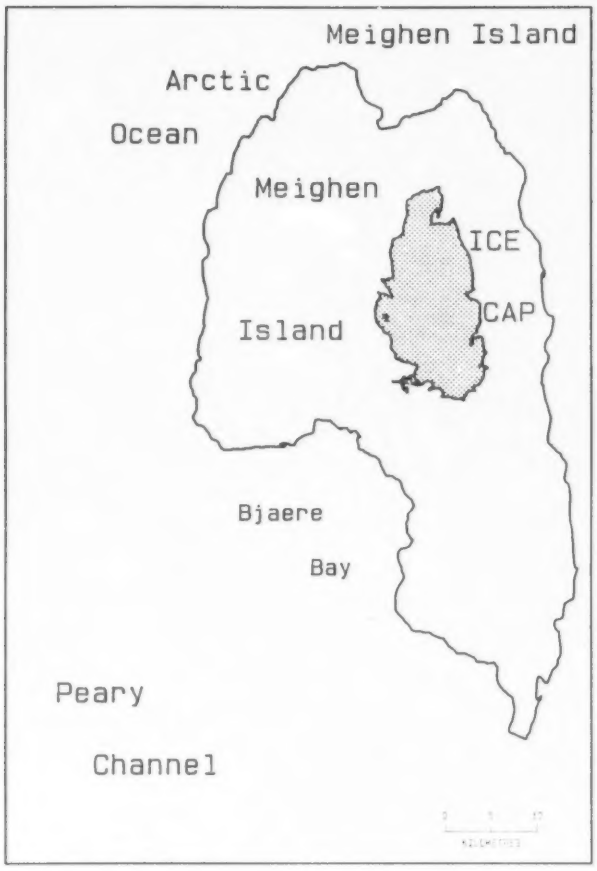


Figure 2. The Meighen Ice Cap.

topography of the traverse and the limited visibility. As there is no point on the line from which both ends are visible, initial theodolite bearings were supposed to be made from shots to additional control monuments on each side. Temporary poles would then be placed in the snow pack along these bearings to direct the levelling down each side in turn from a shared location at the highest point of the traverse. In fact, fog and snow made shots, to all but one other monument on one side, impossible, so a less accurate bearing had to be used and extended by intermediate theodolite plunging across the ice cap. The result was that the line was inadvertently redirected by about 100 m after the 7260 m traverse and had to be connected to the monument by a short additional traverse beside the ice cap.

The levelling procedure used is that taught to student geomorphologists and is not novel or complex. The levelling apparatus consists of a tripod-mounted telescope or level that can only move about a vertical axis, and a stadia rod that is held vertically on the surface at any points whose elevation it is desired to compare. As data are normally required for points along a line that ranges in elevation by more than the height of the stadia rod, a 'leap frog' procedure is adopted in which the level and the rod are moved in turn along the traverse and readings are taken from one location to both of every pair of adjacent survey points. If independent distance measurements are being made, the location of the level is not important. The rod locations, however, must be marked for subsequent distance measurement. Alternatively, distances may be obtained by the stadia method involving readings to upper and lower cross hairs whose apparent separation on the rod is directly proportional to the distance from the level to the rod. In this case, the level must be placed directly on the survey line.

The survey was conducted in spring (this is the best time for aircraft access because of summer melting and winter darkness) when a snow pack of about 50 cm covered the ice. Horticultural canes were hammered through the snow to the ice at each rod location and the height exposed was measured to allow calculation of the snow depth, for subtraction from the surveyed surface elevations. These canes also served to mark the locations for subsequent distance measurement.

Due to time constraints imposed by poor weather, the profile could only be surveyed in one direction and was not closed. Nevertheless, the vertical difference between the two ends could be compared to the geodetic data for the control monuments, and a vertical discrepancy of 1.05 m was deduced. This is attributed to some combination of error in the 1960 survey, subsequent solifluction within the gravel around the controls, and accumulated errors in the 1985 levelling. This error meant that the vertical uncertainty along the line was much less than the topographic change observed over most of the traverse.

Profiles of the ice cap for 1960 and 1985 are shown in Figure 3. It is clear that over the 25 years of the study period the average slope has increased. The upper half of the 1985 profile now lies above the 1960 elevations, and the lower half has decreased height. It is important to consider the fact that the profile crosses a dome that is not typical of the whole ice cap but of just the southern part, and furthermore that the upper part of any such three dimensional feature obviously represents only a small part of the total area. The proper interpretation of these results is therefore that the overall mass balance of the ice cap for the past quarter-century has been quite negative. Comparison of the profiles is made easier by Figure 4, which shows the relative change in elevation for interpolated points along the profile. The steep upward slopes towards each end of the graph represent recession of the margin and consequential surveyed surface depression. Although margin recession is interesting (particularly because it changes the areas of the representative zones at the ice cap margin, and so influences proper weighting of stake data), it was not considered useful to locate the margins precisely because the 5 m contour interval of the maps prohibits very detailed topographic comparisons. The small bump visible on the peak of the 1985 profile (but not found on the 1960 data) is an artifact of a quarter-century of snow drifting about huts placed there in the early 1960's. The cause of the relatively less elevated portion of the profile just west of the peak is not known. If these two features are smoothed over, the greatest elevation increase would be about 7 m. The greatest surface depression is at the two margins, which are of about 8 m.

Comparison is made of the results in the case study and the methods in general. As explained in the survey report (Haythornthwaite, 1986), precise quantitative comparisons of the results of the topographic change project and the stake measurement programme are not possible, partly because no stakes lie precisely on the traverse, and largely because of

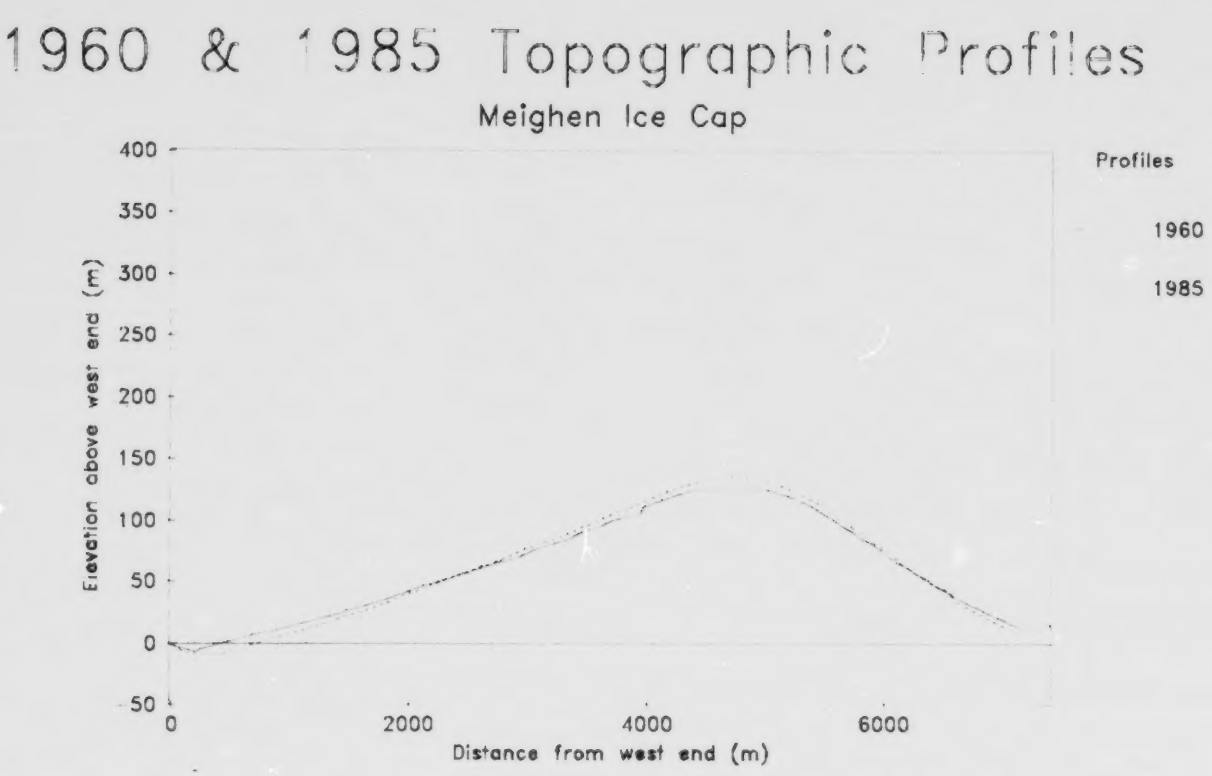


Figure 3. 1960 & 1985 Topographic Profiles. Change is characterized by generally negative mass balance (but with an increase in the elevation of the highest part), slope steepening, and marginal recession.

the practical disadvantages of the stake measurement method as explained below. Nevertheless, a rough analysis is made here for the data from the two stakes nearest the ends of the line and the two nearest the ice cap peak. (A stake originally located on the peak was abandoned when the above-mentioned snow drift became apparent.) Of 20 available annual data for a stake located about 1000 m from the west end of the traverse, the mean annual mass balance measured was -177 Kg m^{-2}. The surveyed mean annual mass balance, calculated by allowing for the density of ice, is about -210 Kg m^{-2}. A similar comparison at the other end of the traverse yields values of -112 Kg m^{-2} and about -100 Kg m^{-2} respectively. These compare fairly well, but for the two highest stakes, the mean stake values are 71 Kg m^{-2} and 31 Kg m^{-2} versus about 240 Kg m^{-2}. If the topographic change data are correct, the stake measurements have been underestimating the magnitude mass balance increase at the highest parts.

If the survey data were in error it could only be because of some unknown systematic inaccuracy of the data collection method that tended to err towards larger elevation increments per survey step as levelling progressed down the slopes. (This is bearing in mind the particular direction that the work was done on each half of the traverse.) As the supposed error in the net difference between the two ends was so much less than the 1960–1985 elevation change over most of the traverse, it seems likely that the stake measurement data are deceptive, and that the levelling survey is a practical alternative method.

Because these results were so encouraging, the Melville South Ice Cap and a small ice cap just west of the Sverdrup Glacier on Devon Island were both traversed in 1986. In the case of the former, as with Meighen, stake measurements are currently still being made. The other ice cap may become the first in a series of new monitoring stations to add to our knowledge. In both of these cases, however, there were no previous surveys of adequate accuracy for comparison, and so the traverses formed the beginning of what will be ongoing monitoring programmes. The stadia technique of distance measurement was used for both of these surveys, whereas the Meighen survey used Electronic Distance Measurement (EDM) equipment. Experience with both techniques suggests that the stadia method is accurate enough for this purpose and the increased time spent levelling is compensated for by the lower logistic and technical complications involved with the EDM.

It is not difficult to suggest ways that the stake measurement data could disagree with the levelling. Several years' data are missing and so various stake measurement results are derived from as few as 19 observations. Furthermore, there is inevitable uncertainty of the degree to which stake observations are representative of the mass balance of the surrounding regions. This has been discussed by many glaciologists, in particular for the high arctic by Arnold

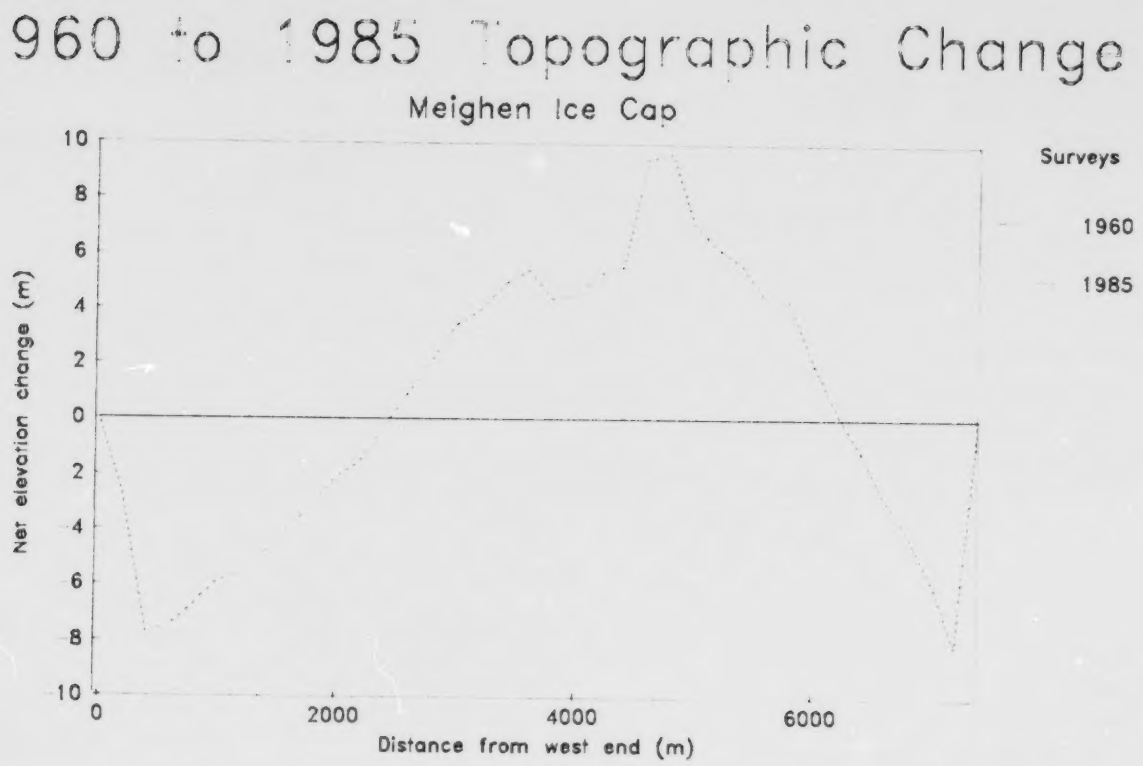


Figure 4. 1960 to 1985 Topographic Change. Vertical differences between the profiles were calculated for interpolated points at every 200 m along the transect. Marginal recession is represented by the steep portions at each end. The peak in the plot is an anthropogenic snowdrift.

(1981), and Koerner (1985). It is the experience of the author (after examining data from stake locations having, for various reasons, duplicate stakes for one or two years) that there is a very low signal to noise ratio. While data obtained from a complete set of stakes probably provide good climatic information for the ice cap as a whole, complete data sets are rarely obtained in practice because of difficulties that cause either missed measurements or truly missing stakes. A consequence of this is that averages derived from the remaining data may be biased by any systematic cause for missing data. For instance, if many are missing because of extremely positive balances, then the remaining data will probably imply too low a balance.

Discussion

A principal advantage of the levelling method is that it need not be repeated annually. While the levelling of transverse profiles conducted so far has taken approximately twice as much time in the field as the stake measurements for the whole ice cap, the benefit of the work is spread over many years. It might be useful to resurvey in about five years, but in the meantime, if it becomes impossible to continue a full stake measurement programme, the long-term continuity of the mass balance record will still be assured. We can now consider logistically simpler versions of the stake measurement method that seek not to establish the actual mass balance of the whole ice cap but instead only to characterize individual years. Such methods might involve a small stake farm or a single row of stakes to monitor the mass balance at different altitudes (Koerner, 1985). Such an arrangement could be measured in a single visit while aircraft wait, thus potentially saving as much as half of the flying hours currently required.

What the levelling lacks in completeness by representing only a two dimensional slice of the ice cap instead of sites spread over three dimensions, it gains by having greater potential resolution along its traverse. Careful selection of the traverse and interpretation of results can allow meaningful extrapolation of conclusions. Stake measurements are particularly hampered by the inevitable discontinuities in each record once a measurement is missed. While they do provide balance data for winter and summer seasons as well as for annual net balances, the latter two types become unavailable for two years if just one year's measurements are missing because the technique also involves temporal comparisons.

Because periodic levelling surveys permit much more efficient and reliable data collection for given resources of aircraft hours, personnel, etc, and because such resource availability may be becoming increasingly unpredictable as well as, perhaps, less available, this method is becoming an increasingly attractive alternative. It is even possible that other ice caps, such as the "new" one on Devon Island, might be added to our network of monitoring stations as this method makes their information increasingly available.

Acknowledgments

I am very grateful to the following for their help and encouragement: Caroline Cyr, J. Peter Johnson, Jr., R.M. Koerner, Leif Lundgaard and Mr. George Hobson of the Polar Continental Shelf Project.

References

Arnold, K.C. 1966. The glaciological maps of Meighen Island, N.W.T. Canadian Journal of Earth Sciences 3(6):903–908.

Arnold, K.C. 1981. Ice ablation measured by stakes and terrestrial photogrammetry. A comparison on the lower part of the White Glacier, Axel Heiberg Island, Canadian Arctic Archipelago. Axel Heiberg Island Research Reports, Glaciology No. 2, McGill University, Montreal, 98 p.

Haythornthwaite, T.W. 1986. Topographic Change of the Meighen Ice Cap. Unpublished M.A. thesis, Department of Geography, Carleton University, Ottawa, Ontario.

Koerner, R.M. 1968. Fabric analysis of a core from the Meighen Ice Cap, Northwest Territories, Canada. Journal of Glaciology 7(51):420–430.

Koerner, R.M. 1985 in press. A new method for using glaciers as monitors of climate. Proceedings of the Glacier Mass-Balance, Fluctuations and Runoff International Symposium, Alma Ata, USSR.

Koerner, R.M., and Paterson, W.S.B. 1974. Analysis of a core through the Meighen Ice Cap, Arctic Canada, and its paleoclimatic implications. Quarternary Research 4(3):235–236.

Paterson, W.S.B. 1968. A temperature profile through the Meighen Ice Cap, Arctic Canada. International Association of Hydrological Sciences Publication 79:440–449.

Paterson, W.S.B. 1969. The Meighen Ice Cap, Arctic Canada: accumulation, ablation and flow. Journal of Glaciology, 8:341–352.

DRAINAGE CHARACTERISTICS OF A GLACIER DAMMED LAKE, KASKAWULSH GLACIER BASIN, SOUTHWEST YUKON TERRITORY

Jennifer N. Kasper and Peter Johnson

Department of Geography, University of Ottawa, Ottawa, Ontario K1N 6N5

Level: J. Kasper, Master's

Abstract

The Kaskawulsh Glacier, in the St. Elias Range, Yukon Territory, dams a small lake against its northern margin in a tributary drainage basin and close to the accumulation zone. The lake has a history of annual drainage events producing a series of depositional sequences. The lake is fed by meltwater from the Kaskawulsh Glacier and three small valley glaciers within the basin. The mean temperature for the influent meltwater is below 1°C from the Kaskawulsh, and ranges between 2.7°C and 4.0°C for the three tributary streams. The variations in influent water temperature produce increasing temperatures with depth. Water current speeds indicate sediment movement into the lake at the bed and at locations through the water column. The different sediment levels were produced by turbidity currents resulting from the temperature and suspended sediment contrasts. High sediment loads in the input streams, coupled with the progressive rise in lake level throughout the season, lead to the formation of retrogressive annual deltaic sequences. Despite this transgressive action, maximum lake levels have been regressing throughout the post-Neoglacial maximum period.

Key words: Kaskawulsh Glacier, St. Elias Range, glacial lake, temperature profile, suspended sediments, transgressive sequences.

Résumé

Le glacier Kaskawulsh, situé dans la chaîne Saint-Élias au Yukon, barre, sur son côté nord, un bassin-versant tributaire proche de la zone d'accumulation, et y a créé un petit lac. Dans le passé, celui-ci s'est vidé chaque année en produisant une série de dépôts sédimentaires. Le lac est alimenté par l'eau de fusion du glacier Kaskawulsh et de trois autres petits glaciers de vallée dans le bassin-versant. La température moyenne de l'eau du premier glacier est moins de 1° C et elle atteint de 2,7 à 4° C pour les trois autres tributaires. Les différences de température des eaux d'alimentation produisent un gradient de température, croissant avec la profondeur. La rapidité des courants indiquent que les sédiments sont brassés dans le fond du lac et à certaines profondeurs. Les troubles en suspension à différents niveaux y sont amenés par les courants de turbidité résultant des différences de température. Les fortes charges transportées par les tributaires, associées à l'élévation graduelle du niveau lacustre au cours de l'été, entraînent la formation de séquences de sédiments deltaïques de transgression. En dépit de celle-ci, le niveau maximal du lac a baissé tout au cours de la période post-néoglaciaire.

Mots-clés: Glacier Kaskawulsh, chaîne Saint-Élias, lac de glacier, gradient de température, troubles en suspension, séquences de trangression.

Introduction

Within the overall framework of a study of the hydrological processes operating in a glacierized basin, an investigation of the cycles of filling and draining of a glacier ice dammed lake was initiated in 1986. The lake is located at 139°07′W,60°46′N, on the north side of the Kaskawulsh Glacier in the St. Elias Range, Yukon Territory (Fig. 1). It is located at an altitude of 1646 m, with the surrounding peaks rising to 3048 m above sea level.

The size of the basin is ca 48.05 km^2, about 10 km long and 5 km deep, and is fed by three small tributary glaciers. The three glaciers are of different types, one a surging glacier (surging at present), one a non-surging glacier and the last a stagnant glacier. The three vary in length from 4.6 to 5.4 km.

The basin is characterized by large amounts of ice-cored moraine, as well as sections of collapse features and kettle-type lakes. The highest meltout rates of the ice core occur near the terminuses of the surging and non-surging glaciers, while the less recent meltout features are situated near the terminus of the stagnant glacier (Fig. 2).

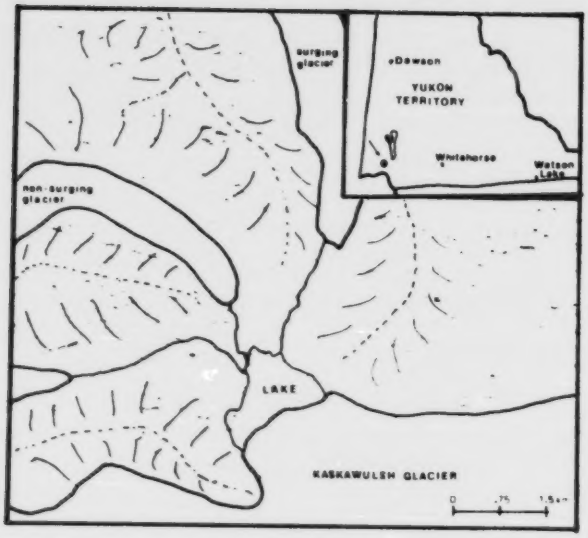


Figure 1. Glacier-dammed Lake Basin.

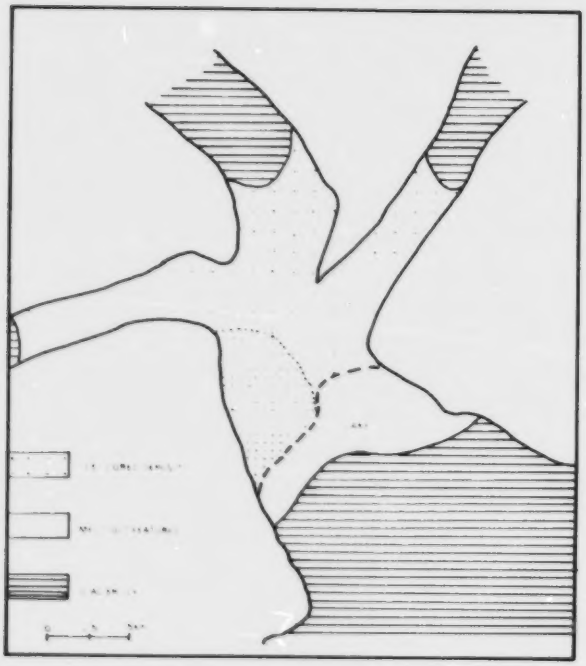


Figure 2. Distribution of deposits in basin.

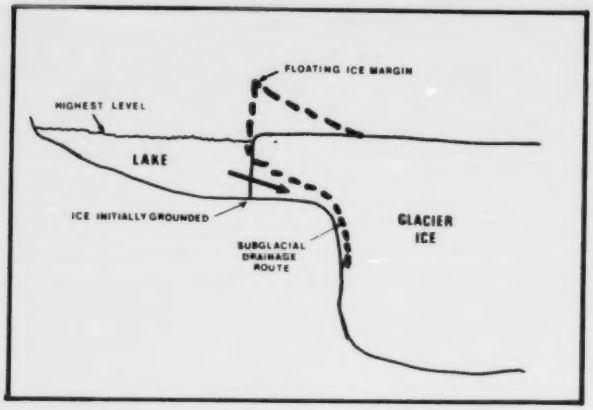


Figure 3. Lake drainage mechanism.

Casual observations of the lake by research parties and logistics personnel over the last 20–25 years indicate that the lake drainage is an annual event which normally occurs between late July and early September. Air photo coverage of the lake (Aug. 1951, Aug. 1972, Aug. 1977) suggests a subglacial mechanism of drainage, initiated by floating of the glacier margin as the lake fills (Figs. 3 & 4). Once the ice margin has lifted, it is thought that the initiation of drainage leads to further enlarging of the channels, either under or within the ice mass (Liestol, 1955; Nye, 1976), which allows the lake water to drain. Figures 5 and 6 are photos of the lake taken in 1986. Figure 5 shows the lake during its filling stage. From the level shown in the June 27th photo, the lake rose a further 15 m during the time monitored. Further casual observations led to the belief that the beginning of August had seen the lake rise to within a couple of meters of its maximum. When records ended on August 7th, the rate of filling had slowed considerably. Average rates of lake level rise in mid-July were 0.03 m/hr, and on August 6, the rate was down to only 0.006 m/hr. Figure 6 shows the lake completely empty. A local pilot noted the initiation of drainage on September 5th. The rate of water level drop seemed to increase through the 8th and 9th, to complete draining by the 10th.

The lake is fed by water from two major sources. The first is from the Kaskawulsh Glacier. Input from this source is impossible to measure due to the extent of the ice margin area. Channels bringing meltwater into the lake can be either supraglacial, subglacial, or englacial. Meltwater is also contributed by streams along the lateral margins of the ice mass. The main characteristics of the meltwater being provided by the Kaskawulsh Glacier are its temperature, which is always less than 1°C, and its very low sediment loads.

The second major source of water for the lake are the three basin streams which are glacier-fed. The regimes of these three streams are all irregular. The Surging Glacier stream is characterized by sporadic water release from the glacier, caused by the opening and closing of passages within the ice mass. The Non-surging Glacier stream showed a variation with the temperature as well as diurnal change, but the major irregularity within its discharge pattern was caused by outburst floods. These floods were caused by course changes

Figure 4. Floating ice margin.

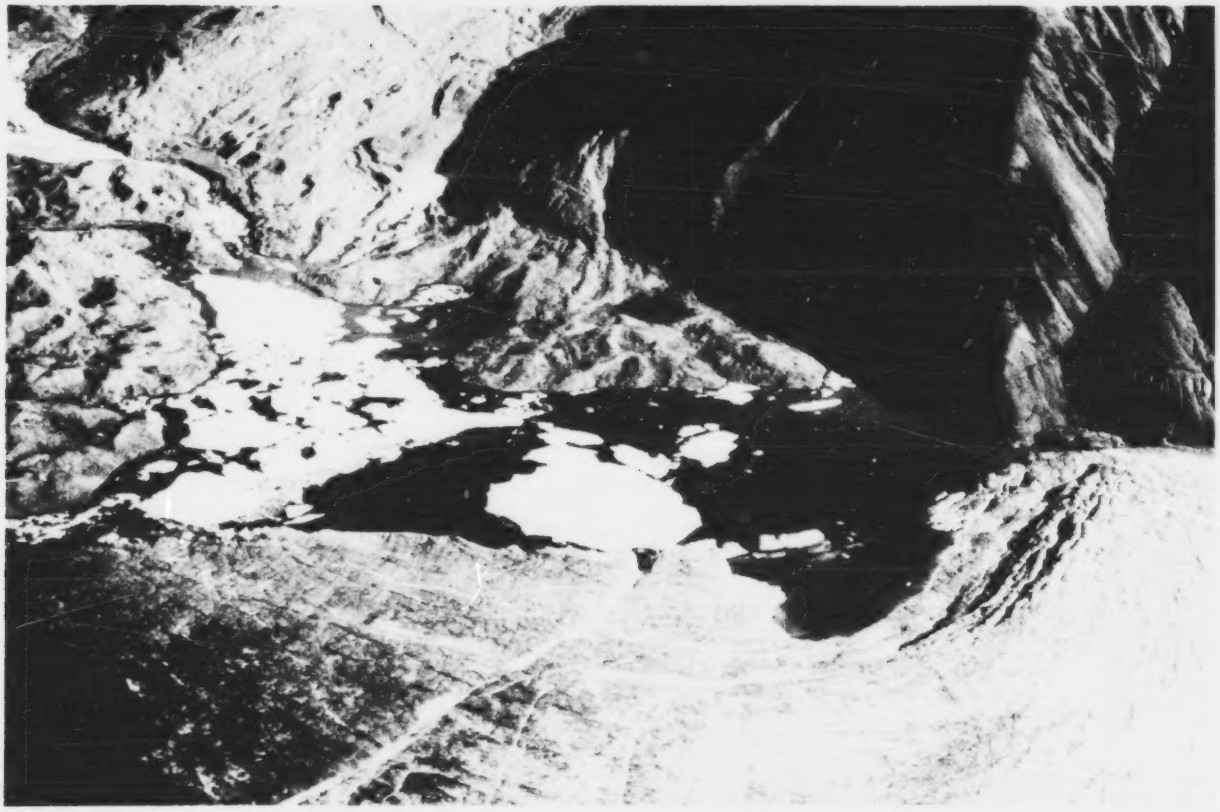


Figure 5. June 27 photo of lake filling.

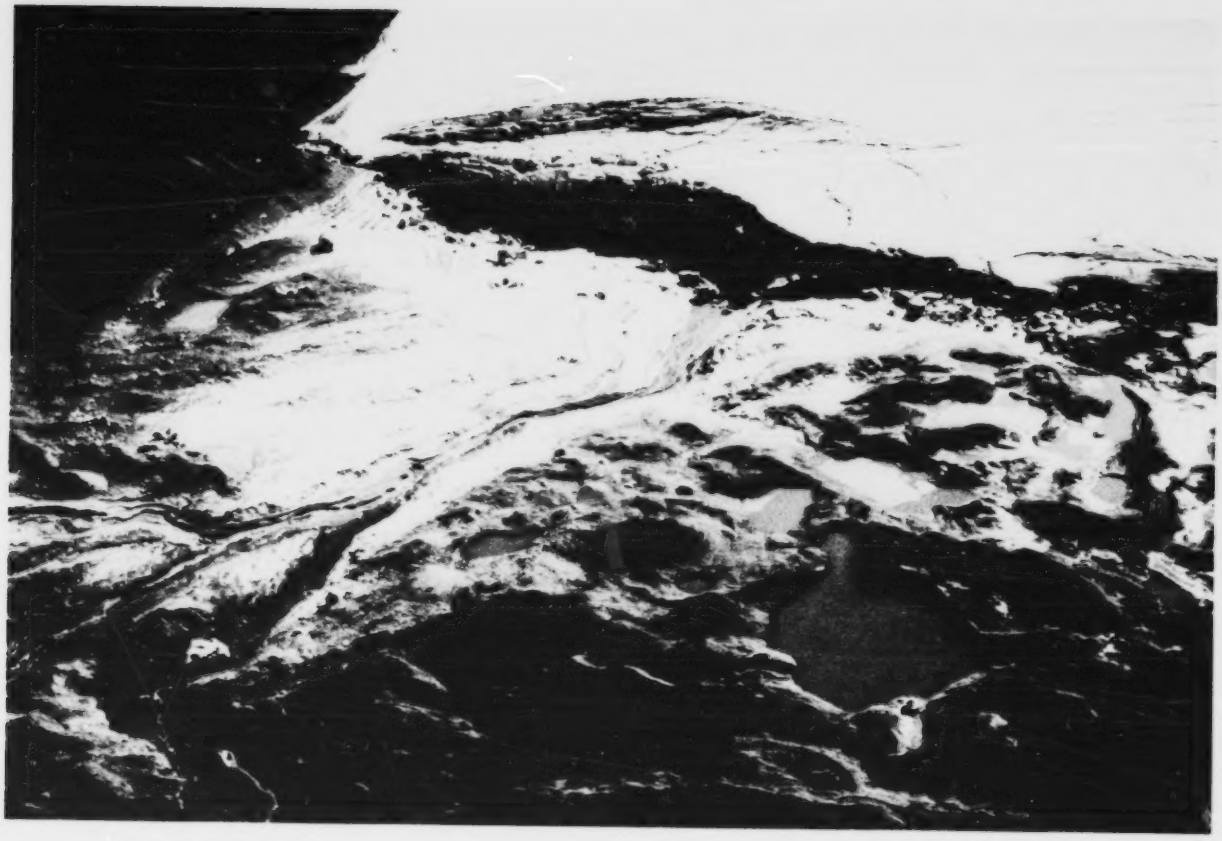


Figure 6. September 11 photo of drained lake bed.

due to tunnel collapse in the ice-cored moraines. The Stagnant Glacier's discharge was not monitored, but generally it increased through the summer as the ablation season advanced. It also showed normal diurnal variations.

The temperature characteristics of the stream water entering the lake have been modified from their point of origin in a glacier into the lake. The temperature fluctuated within the range of 2.7°C to 4.0°C, both on a diurnal basis and depending on climate. Therefore, the two major sources of water feeding into the lake are different in that one is warm and the other is cold.

The suspended sediment input into the lake is predominantly derived from the three streams. The Kaskawulsh Glacier has little surface debris, and there is not much evidence within the basin of sediment movement by the glacier into the area. The sediment supply regime varies from stream to stream as a result of difference in discharge regimes. The Surging Glacier stream derives most of its load directly from the glacier, and as such it is very fine in composition. The Non-surging Glacier stream, on the other hand, derives most of its load from course changes in the ice-cored moraines. The quantity of sediment being carried by the stream is highly variable due to changes in channels and drainage patterns. The third stream experienced what was apparently a generally increasing trend in suspended sediment load throughout

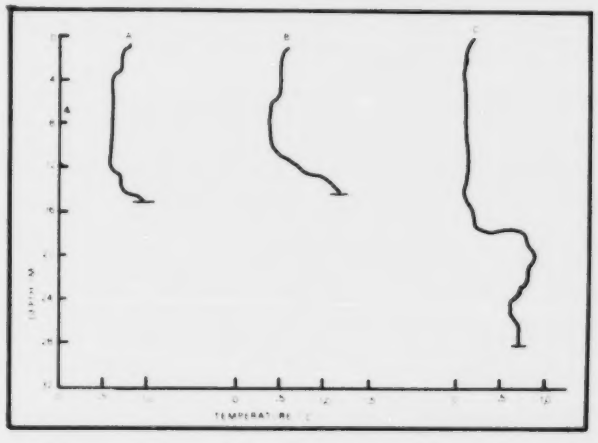


Figure 7. Representative temperature profiles.

the season as a result of amplified mudflow and slump activity from the valley sides.

Preliminary results indicate that the majority of the water entering into the lake is derived from the Kaskawulsh Glacier, since the overall lake temperature is less than 1°C. Lake

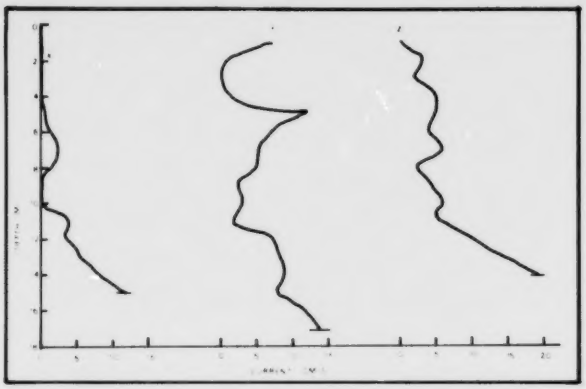


Figure 8. Representative lake current profiles

temperature profiles taken at several locations show an increase in temperature near the bottom of the water column (Fig. 7). This increase in temperature towards the lake bottom agrees with data provided by studies on Summit Lake, B.C. (Gilbert, 1972). The increase in temperature results from the development of major density contrasts between the cold lake water (which is relatively sediment-free) and the sediment-laden, warmer stream water. The temperature and sediment contrasts initiate turbidity flows at the lake bed and within the water column.

The presence of these turbidity flows was detected by recording current measurements for different locations within the lake, concentrating mostly on the stream mouth areas (Fig. 8). These profiles show several currents at depths of 4–5 m, 7–8 m, and 16 m. Current measurements fluctuated extensively near the stream mouths (0 cm/s to 19 cm/s) and, to a more limited degree (0 cm/s to 6 cm/s), closer to the ice margin. All profiles show peak current flows at the lake bed, and this information is corroborated by the sediment dispersal pattern seen after drainage (see Fig. 6). The sediments seem to flow directly towards the ice margin along the lake bed, with very little dispersal into large parts of the area which is covered by water when the lake is full.

There is also evidence of the formation of turbidity flows during the filling of the lake. At the mouths of the streams, the heavily sediment-laden stream water experienced strong turbulent flow. There was a general trend, in the upper layers of the water column, for return flow, due in part to the presence of grounded icebergs. However, grounded ice cannot wholly account for the sharp boundary between the lake water and the stream water (Fig. 9). This boundary seems to have prevented dispersal of the sediments throughout the water column. The only possible explanation for this boundary is the marked density differences between the lake and stream water.

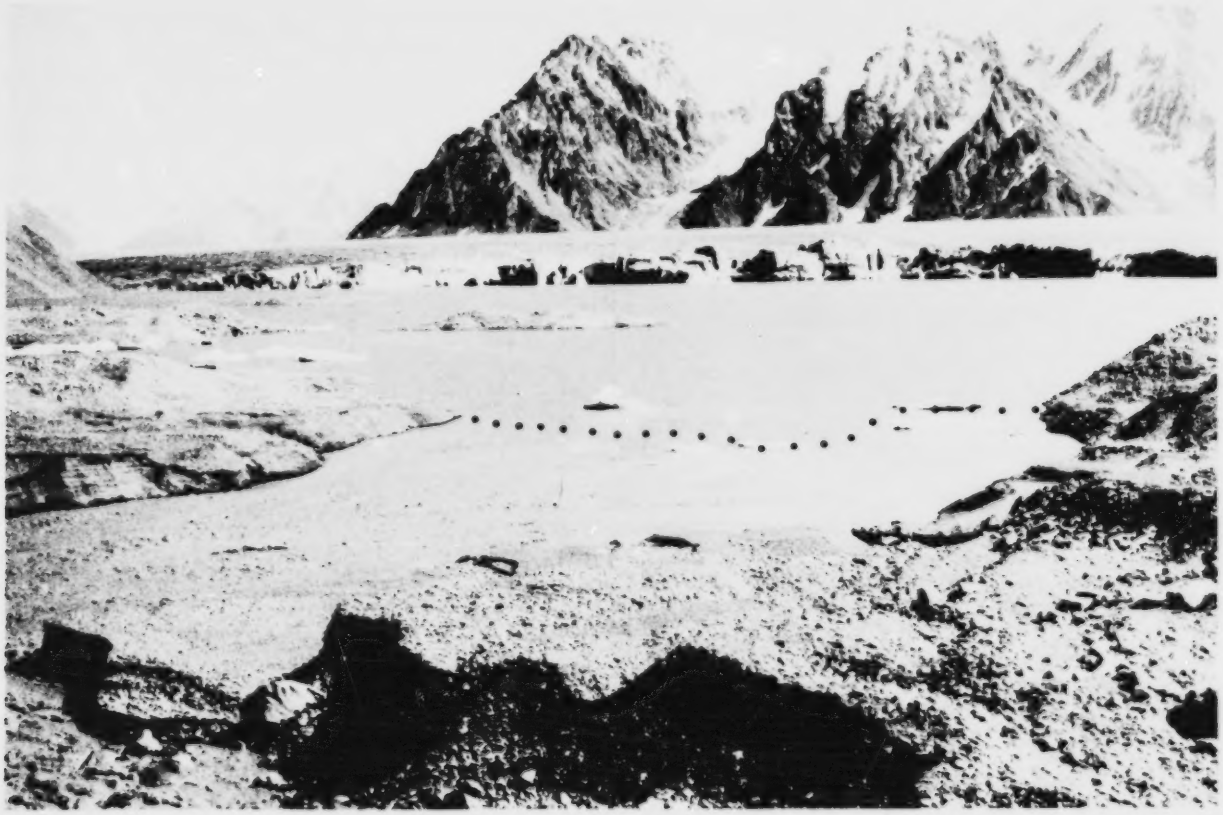


Figure 9. Plunge line at stream water/lake water interface.

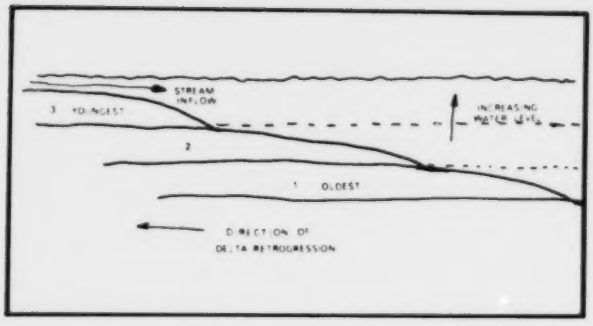


Figure 10. Retrogressive delta construction.

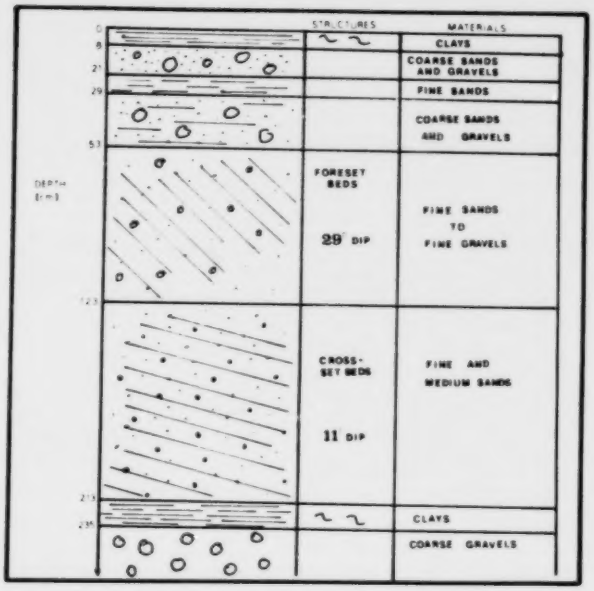


Figure 11. Paleosequence with alternating stream and lake deposits (surging glacier stream section)

The morphological features resulting from the filling and draining of the lake are a series of retrogressive deltas and river terraces. As the lake level rises, the delta-building process migrates further upstream. In this way, when the lake eventually drains, the delta can be seen to have been built up in multiple stages moving further up the stream channel (Fig. 10). The development of river terraces is also associated with the changing lake level. As the lake level drops, the stream also drops its base level. This initiates the formation of a series of step-down terraces. Hence, the sedimentary sequence is made up of terrace and delta-type deposits (gravels) overlain by fine, silty lake deposits. This alternation has been occurring throughout the history of the glacial lake (Fig. 11).

The study of paleosequences in the basin provides information regarding the processes which operated in the past. For example, clay deposits, ranging in thickness from 1.3 m to 4.5 m at different locations within the basin, seem to indicate that at certain periods in the history of the lake, drainage was not an annual phenomenon, but that the lake persisted for long periods of time without draining.

Within these massive clay deposits, layers or sequences with different characteristics can be separated. For example, in one section, there is a 1.8 m thick section of clays which grade downwards from an annual type layering, possibly varves or rhythmites, into massive clay units with no structure. At other places within this section, there are examples of cross bedding in a 1.2 m thick unit, as well as load structures. Hence, in the basin, separate clay units can measure from 10 cm to 2 m thick, and can exhibit a layering sequence (still water), or be massively bedded, or can contain ripple and cross bedding features (indicative of flowing water). These different types of units are indicative of a great variety of depositional conditions existing in the basin in the past.

Most of the massive clay deposits seem to be at a much higher elevation than the level the lake presently fills to. On some of the till mounds there are relic lake sediments located at the peak of these topographic features. These sediments provide information on the depth and extent of the lake in the past, since strandlines for paleolake levels are not preserved due to slope processes.

Conclusion

The evidence preserved in the stratigraphic record of the basin suggests that the lake had a semi-permanent existence at higher levels. The annual drainage, which characterizes the lake at the present time, seems to have developed rather recently. Nonetheless, the information on the hydrological processes operating in the basin today can be used to interpret both paleosequences and modern day sequences.

Acknowledgments

Financial assistance for this project was provided by the D.I.N.A. Northern Scientific Training Program, as well as by the Natural Sciences and Engineering Research Council of Canada Operating Grant #A-7485 (Dr. P.G. Johnson). Logistics support was provided by the Arctic Institute of North America (Kluane Lake Research Station). Special thanks go to Peter Johnson, V. McIntyre, J. Gagnon, R. Guay, and P. Harris for their help and support in the field.

References

Gilbert, R., 1972. Drainings of ice-dammed Summit Lake, British Columbia. Inland Waters Directorate, Water Resources Branch. Scientific Series #20.

Liestol, O., 1956. Glacier-dammed lakes in Norway. Norsk. Geogr. Tidsskr., Vol. 15, pp. 122–149.

Nye, J.F., 1976. Water flow in glaciers: Jökulhaups, tunnels and veins. Journ. of Glaciology, Vol. 17, No. 76, pp. 181–207.

THE FREEZING AND THAWING OF A SUBARCTIC FEN, SCHEFFERVILLE, QUÉBEC

C.M. Kingsbury and T.R. Moore

Department of Geography, McGill University, Montreal, Quebec H3A 2K6

Level: C.M. Kingsbury, Master's

Abstract

Northern environments are highly susceptible to thermal change caused by resource development activities (e.g. construction of pipelines, roads and railways). In northern Canada, 25% of the landmass is composed of peatlands. Background information is needed about natural thermal regimes of peatlands, so that if they are disturbed, damage can be kept to a minimum.

From late October, 1984 to early August, 1985, temperatures were measured to a depth of 1.5 m in a subarctic fen near Schefferville, P.Q. Winter cover components (snow, white and black ice, and seasonal groundfrost) were also monitored. Freeze-up was initiated by a rapid groundfrost development (23.3 mm per day) and ice growth in wet depressions (e.g. pools). However an insulating snowcover of 13 cm (in Nov.) greatly reduced the growth rate of groundfrost to 3.6 mm per day. The snowcover gradually grew to a maximum thickness of 68.0 cm, which decreased the freezing rate to 0.6 mm per day by May. Also, a lowering of the water-table within the fen created a dehydrated layer beneath the freezing front. The maximum freeze depth of about 1 m was obtained in May.

Thaw began in early May, with the snowcover beginning to melt. Subsequently, meltwater pooled on the frozen peat and began to warm the surface layers (−2.9 to +4.8°C). The groundfrost began to melt from both above and below, creating a major ice lens within the peat, which finally melted completely in early August. With the frost thawed, the temperature in the fen warmed up quickly to an average peat temperature of 15.7°C.

Key words: Fen, subarctic temperature, seasonal groundfrost, ice, snow, freeze-up, thaw, dehydrated layer.

Résumé

Les milieux nordiques sont extrêmement sensibles aux modifications thermiques causée par la mise en exploitation des ressources (p. ex. par la construction d'oléoducs, de routes ou de voies ferrées). Vingt-cinq pour cent du territoire émergé du Canada sont recouverts par des marécages tourbeux. Il faut donc recueillir des données sur le régime thermique de ces sols, afin de pouvoir réduire le plus possible les dommages causés par leur bouleversement.

Les auteurs ont mesuré, à 1,5 m de profondeur, les températures d'un marécage tourbeux subarctique de la région de Schefferville, Québec, de la fin d'octobre 1984 au début d'août 1985. Ils ont également mesuré la progression de la couverture hivernale (neige, glaces d'eaux pure et boueuse, et sol gelé l'hiver). Le gel commença par une congélation rapide du sol en profondeur (23,3 mm par jour) et des eaux des dépressions humides (mares). Cependant, une chute de 13 cm de neige en novembre ralentit fortement le gel du sol à 3,2 mm par jour. La couverture neigeuse isolante s'épaissit graduellement jusqu'à 68,0 cm, réduisant la progression en profondeur du gel du sol à 0,6 mm par jour en mai. De plus, l'abaissement du niveau de la nappe phréatique dans le marécage créa un horizon déshydraté en-dessous de la zone de congélation. L'épaisseur maximale de la couche congelée, soit 1 m, fut atteinte en mai.

Le dégel commença au début de mai, alors que la couverture nivale commença à fondre. Ultérieurement, les eaux de fusion se rassemblèrent au-dessus de la tourbe gelée, en réchauffant les couches supérieures de celle-ci (de −2,9° à + 4.8°). Le sol commença à dégeler par ses couches inférieure et supérieure, qui délimitèrent ainsi une lentille de glace de grande taille au sein de la tourbe, laquelle finit par dégeler complètement au début d'août. La glace étant entièrement fondue, la température du marécage s'éleva rapidement jusqu'à une moyenne de 15,7° C.

Mots-clés: marécage tourbeux, température, sol gelé l'hiver, glace, neige, gel, dégel, horizon déshydraté.

Introduction

The thermal regime affects the biological activity of a mire, since the start and end of the growing season are strongly associated with soil thawing and refreezing (Ryden and Kostov, 1980). Though peatlands have been extensively studied, little research has been devoted to the freeze-thaw cycle, which can exist for more than six months a year.

The freeze-thaw cycle of the peatland starts in the late fall, when the peat is saturated due to rain and reduced evaporation (Ryden and Kostov, 1977). Freezing of the water occurs and this forms ice in the wet depressions and seasonally frozen peat in the organic soil. The thermal properties of peat enable it to freeze relatively quickly during the initial freeze-up (Brown, 1970; Brown and Williams, 1972). Once an insulting snow cover forms, the thermal gradient is reduced, and both ice and frozen peat growth is hindered (Sonesson, 1969; Brown and Williams, 1972; Eurola, 1975; Price, 1983a; Kingsbury, in press).

The location of the water table both hinders and promotes freezing in mires. Over the winter, the water table falls steadily due to a reduced hydrologic activity (Ingram, 1983; Price, 1983b) and to an upward moisture gradient towards the freezing front (Hoekstra, 1966; Juusela, 1967; Pavlova, 1970; Jumikis, 1977). The frozen peat which forms directly from *in situ* freezing stops, when the water table falls below the freezing front. However a different type of segregated ice forms, with visible ice lenses (Shumskii, 1964; Penner, 1964) between the freezing front and the lowering water table. By this time in the winter, the cover components have developed in the peatland. They consist of white and black ice found in wet depressions, frozen peat consisting of

segregated ice and a snow cover (Kingsbury, in press). Snow melting processes commence with warming air temperatures and rainfall. The meltwater migrates to the surface of the mire and starts to warm the peat surface (Thom, 1971). After snow melt, evaporation begins with the heating of the mire surface, which dries out the surface peat (if not replenished by rains) and creates an ice lens within the peat (Cowell *et al.*, 1978). Eventually heat fluxes warm up the subsurface layers and the seasonally frozen peat melts.

The purpose of the study was to document the physical freeze and thaw of a subarctic mire. This project is part of a broader investigation, dealing with nutrient leaching into subarctic peatlands.

Study area

The study mire was located near Schefferville, Quebec, (lat. 54°48′N, long. 66°49′W) and is found in the discontinuous permafrost zone (Brown, 1970) of the low subarctic wetland region (Zoltai and Pollett, 1983). The 25 year mean annual temperature is −4.8°C, having a max/min range of +14.4 to −30.1°C, during the study period (November to August), with the mean annual precipitation being 784.7 mm, of which 378.0 mm is water equivalent of snow (Barr and Wright, 1981). The specific study site is a fen based on the Sjörs (1950) classification. The mire (locally called Aries fen) has a surface area of 2 ha, and is surrounded on the north and east sides by black spruce (*Picea mariana*) forest, with the south edge being a lake and the west end a small stream. The bedrock underlying the mire is dolomitic in nature, and no permafrost is present. The vegetation found on the peatland consists mostly of *Carex* sedges, with some *Ledum* shrubs and *Sphagnum* hummocks, with the peat depth ranging from 10 cm on the extreme margins to over 150 cm in the fen location.

Methods

Two temperature cables, 1.5 m long, were placed into the fen within 2 m of each other (Fig. 1). The multi-thermistor cables were inserted within a CPVC half inch pipe and thermistors (Fenwall #GB32P2) were attached at 10, 25, 50, 75, 100, 125, and 150 cm depths from the surface. Readings by a multimeter were taken at approximately 2 week intervals from October, 1984 to August, 1985. The accuracy of the thermistors, based on a 0°C waterbath calibration, ranges from 0.05 to 0.20°C, with the lower limit being associated with values near 0°C.

The winter cover components of the fen, were measured within a 5 m radius of the temperature cables. To reduce the disturbance of the natural winter cover, measurements were made only 10 times during the study period. This consisted of 7 sampling periods during freeze-up and 4 for the thaw, with one sampling date being common to both. Snow depths and water equivalents were obtained by a series of

Figure 1. Fen location on Aries fen, indicating thermistor placement and the study site.

snowpits. The ice and frozen peat penetration depths were determined by drilling holes through the frozen layers using a lake ice auger and measured by a measure stick.

The water table was located by a peat water sampler, adapted from one used at the Experimental Lakes Area. The sampler consists of a thin metal outer tube which is sealed at one end. A few mm above the seal are a set of drilled holes. Contained within the metal tube, is a tight fitting tygon tubing which extends from just above the holes, to out of the metal casing and is connected to a 250 ml bottle attached to a hand-held vacuum pump. The sampler was placed in the drilled hole and pushed down 10.0 cm at a time, until a water sample was obtained, which was assumed to be the water table level.

Results

The winter of 1984–85 was a low snow year in the study region, since only 278.5 mm of water equivalent of snow fell. This amount is 1.0 standard deviation (S.D.) below the 25 year mean for the "snow year" (July to June), which is 377.1 mm of water equivalent (Barr and Wright, 1981). A snow course operated by the McGill Subarctic Research Station (2.5 km north of the study site), illustrates the effect of this low snow year on a peatland snow cover accumulation pattern. The 7 year mean snow depth for the snow course mire, based on an exposed and margin site, was 56.6 cm (S.D. 10.0 cm). For the 1984–85 winter the average snow cover thickness was 32.1 cm, 2.5 standard deviations below the mean. The annual mean temperature of −4.9°C observed for the "snow year" was close to the long term mean, along with the annual rainfall (457.6 mm) for the 1984 season. However, the cumulative May to July precipitation value (111.7 mm) was low, being 1.5 standard deviations below the 25 year mean (194.5 mm).

Freeze-up commenced on October 28, 1984 and melt of the seasonally frozen peat occurred on July 19, 1985 for the fen, and completely for the mire on August 5, 1985 (Fig. 2). Figure 3 indicates the depth of freeze into the fen with time, as being a curvilinear relationship. The initial freeze growth was rapid, but it decreased with increasing time. A maximum freeze depth of 90.0 cm was obtained in May, as noted by the 0°C isotherm (Table 1) which also had a mean freeze rate of 4.8 mm per day. Individual growth rates reflected change with time. A quick penetrating freeze of 76.6 mm per day was initiated at the start of freeze-up, which decreased to 2.6 mm per day for December. In January a lowering water table raised the rate to 9.2 mm per day. The growth rate then steadily declined to 0.9 mm per day in early May.

Included in the seasonally frozen peat are two layers of segregation ice (Fig. 2). Layer A is composed of the surface ice cover and segregated ice with non-detectable ice lensing which formed a solid ice layer. Layer B is formed from the lowering of the water table and the segregation ice consists of visible ice lensing, giving the appearance of a dehydrated layer with ice lenses (Kingsbury, in prep.) Frozen layer A grew at a mean rate of 3.0 mm per day (Fig. 3). Initial freeze-up was noted by a rapid frozen peat ice development of 23.3 mm per day (Table 1). This growth rate was reduced by a magnitude of 10 by a 13.0 cm snowpack development in late November. In December, the colder air temperatures managed to penetrate the forming snowcover. This was

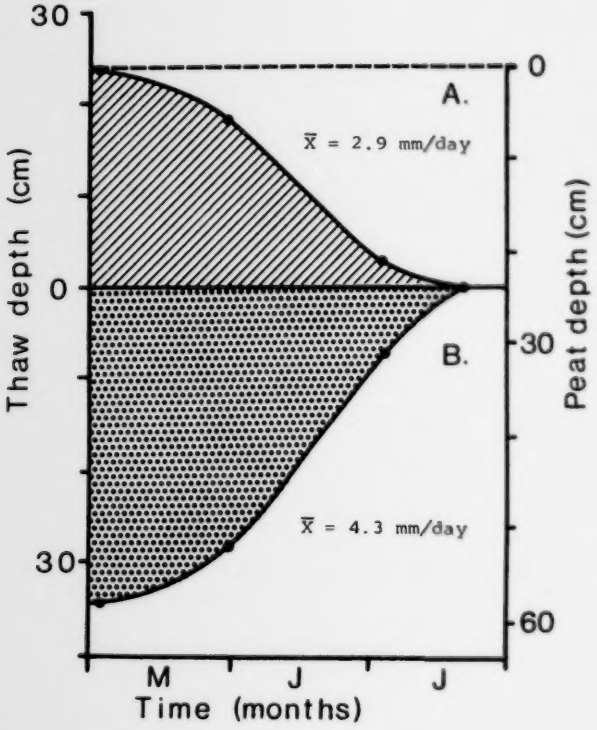


Figure 2. 1984–85 Winter cover components and isotherms for Aries fen.

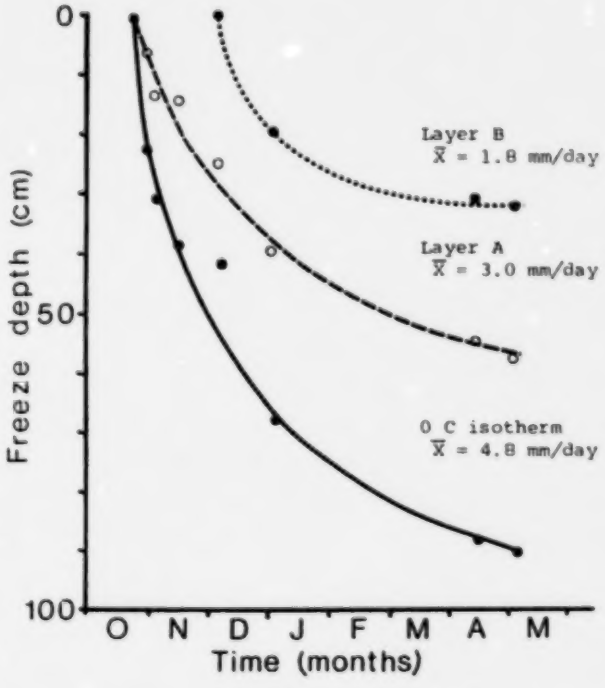


Figure 3. Seasonally frozen peat depths of freeze for Aries fen.

TABLE 1
Seasonally Frozen Peat Growth Depths and Rates, during the 1984–85 winter for a subarctic fen.

Sample Date	Days*	Frozen peat Depth (mm)*				Growth Rates (mm per day)			
		A	B	0°C		A	B	0°C
Oct. 28 '84	0	0.0	0.0	0.0		0.0	0.0	0.0
Oct. 31 '84	3	70.0	0.0	230.0		23.3	0.0	76.6
Nov. 5 '84	5	40.0	0.0	80.0		8.0	0.0	16.0
Nov. 22 '84	17	40.0	0.0	70.0		2.3	0.0	4.1
Dec. 7 '84	15	100.0	0.0	40.0		6.7	0.0	2.6
Jan. 4 '85	28	150.0	200.0	260.0		5.4	7.1	9.2
April 4 '85	88	150.0	120.0	190.0		1.7	1.4	2.2
May 5 '85	31	20.0	10.0	30.0		0.6	0.3	0.9
TOTAL =	187	570.0	330.0	900.0	X =	3.0	1.8	4.8

*from last sample date
note: A,B refers to layers of segregated ice, and 0°C is the 0°C isotherm

reflected by the upper peat having temperatures of about −19.8°C and the increased growth rate of 6.7 mm per day.

An increasing snow cover (maximum depth 68.0 cm), warmer air temperatures and a decreasing water table reduced the rate of freeze to 0.6 mm per day by early May. The maximum freeze depth for layer A was 57.0 cm (Table 1) and the mean growth rate (Fig. 3) for layer B was 1.8 mm per day, based on a 187 day freeze. Layer B was controlled by the 0°C isotherm and the water table level. This was reflected in its growth rates (Table 1). Between December and January a growth rate of 7.1 mm per day was noted. It was attributed to the initial drop of the water table. Thaw rates steadily declined to 0.3 mm per day for May, due to the freeze limitation created by the watertable falling below the 0°C isotherm.

TABLE 2
Seasonally Frozen Peat Thaw Depths and Rates, during the 1985 spring for a subarctic fen.

Sample Date	Days*	Frozen peat Depth (mm)*				Thaw Rates (mm per day)			
		As	Ab	Bb	0°C	As	Ab	Bb	0°C
May 5 '85	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
May 29 '85	24	50.0	70.0	80.0	200.0	2.1	2.9	3.3	8.3
July 3 '85	29	150.0	200.0	180.0	0.0	3.8	5.1	4.6	0.0
July 19 '85+	16	30.0	70.0	70.0	700.0	1.8	4.3	4.4	43.7
TOTAL =	79	230.0	340.0	330.0	900.0	X = 2.9	4.3	4.2	11.4
TOTAL = 570.0						7.2		8.5	

*from last sample date
+estimated melt for the last 100.0 mm ice lens
note: As = layer A surface melt; Ab = layer A below melt; Bb = layer B below melt; 0°C = 0°C isotherm

Thaw began in early May, with the snow cover beginning to melt. Subsequently, melt water pooled on the frozen peat and began to warm the upper 10 cm of peat (−2.9 to +4.8°C). Through June and into July the top 20 cm surface had thawed and the melt water had evaporated from the peat. The surface melt created a major ice lens within the peat, which finally melted in late July for the fen, and completely for the mire in early August. The temperature in the fen warmed up quickly after the thaw (Fig. 2) and the range of thaw rates were 0.0 to 43.7 mm per day, with a mean rate of 11.4 mm per day for the 0°C isotherm (Table 2). The changes in the thaw rate reflected an initial downward melt of 8.3 mm per day, followed by a period of undetectable thaw. Then, a rapid decay of 43.7 mm per day melted the remaining seasonally frozen peat.

Layer A began to melt from both above and below, creating a major ice lens within the peat. Figure 4 shows that rates greatly differ between the surface (2.9 mm per day) and the below (4.3 mm per day) thaw, based on physical measurements of the ice lens.

The upward thaw of layer B was estimated from the change in the water table and the bottom layer of layer A, since the upward thaw can not be directly determined from the 0°C isotherm (Fig. 2). A mean thaw rate of 4.2 mm per day (Table 2) was noted for layer B. The fluctuations indicate a slightly faster thaw at the start, which decreased below layer A's rate in early July. However, in late melt the below thaw rates for both layer A and B were similar.

TABLE 3
Freeze and Thaw Rates for subarctic mires.

Freeze Rate (mm per day)	Thaw Rate (mm per day)	Source
4.3	3.1	Eurola (1975)
2.5 — 4.6	n.d.	Price (1983a)
1.3 — 4.7	5.4 — 12.6	Moore (unpub. man.)
4.8	11.4	PRESENT STUDY
4.2 — 5.0	8.7 — 13.5	Brown & Williams (1972)
n.d.	4.1 — 4.6	FitzGibbon (1981)

note: n.d. = no data

Discussion

Though this study was based on a single winter, which happened to be a low snow year, followed by a dry spring and early summer, it is believed that the results are reasonably typical. The preceding autumn precipitation and temperatures for the winter were similar to the norm for the study region, and all of the cover components were pesent. The mire freeze-up was downward, unlike permafrost situations were freezing occurs from both above and below (Ryden and Kostov, 1980). A change in environmental conditions (i.e. snowcover thickness) was reflected by the frozen peat, in its fluctuating growth rates. The 0°C isotherm penetration into the peat (90.0 cm) was comparable to other subarctic Quebec peatlands, having a range between 20.0 to 100.0 cm (Moore, unpub. man.). The rate of freeze and thaw was also similar to other subarctic mires (Table 3). Overall, the fen freeze-up and thaw followed the same basic pattern observed by Brown and Williams, 1972; Eurola, 1975; Ryden and Kostov, 1980; FitzGibbon, 1981; Price, 1983a; Moore, unpub. man. Within the 0°C isotherm, different forms of segregated ice were present. Though the ice types had different specific characteristics (i.e. physical appearance, formation), the same general freeze-thaw pattern occurred for both. The specific differences were related to influences by environmental factors during the freeze-up and thaw of the segregated ice. However, there was no difference within or between the freeze and thaw rates, based on the findings of the Mann-Whitney U test at the 95% significance level. This indicates the strong interrelationship within the segregated ice (between its two forms) in seasonally frozen peat.

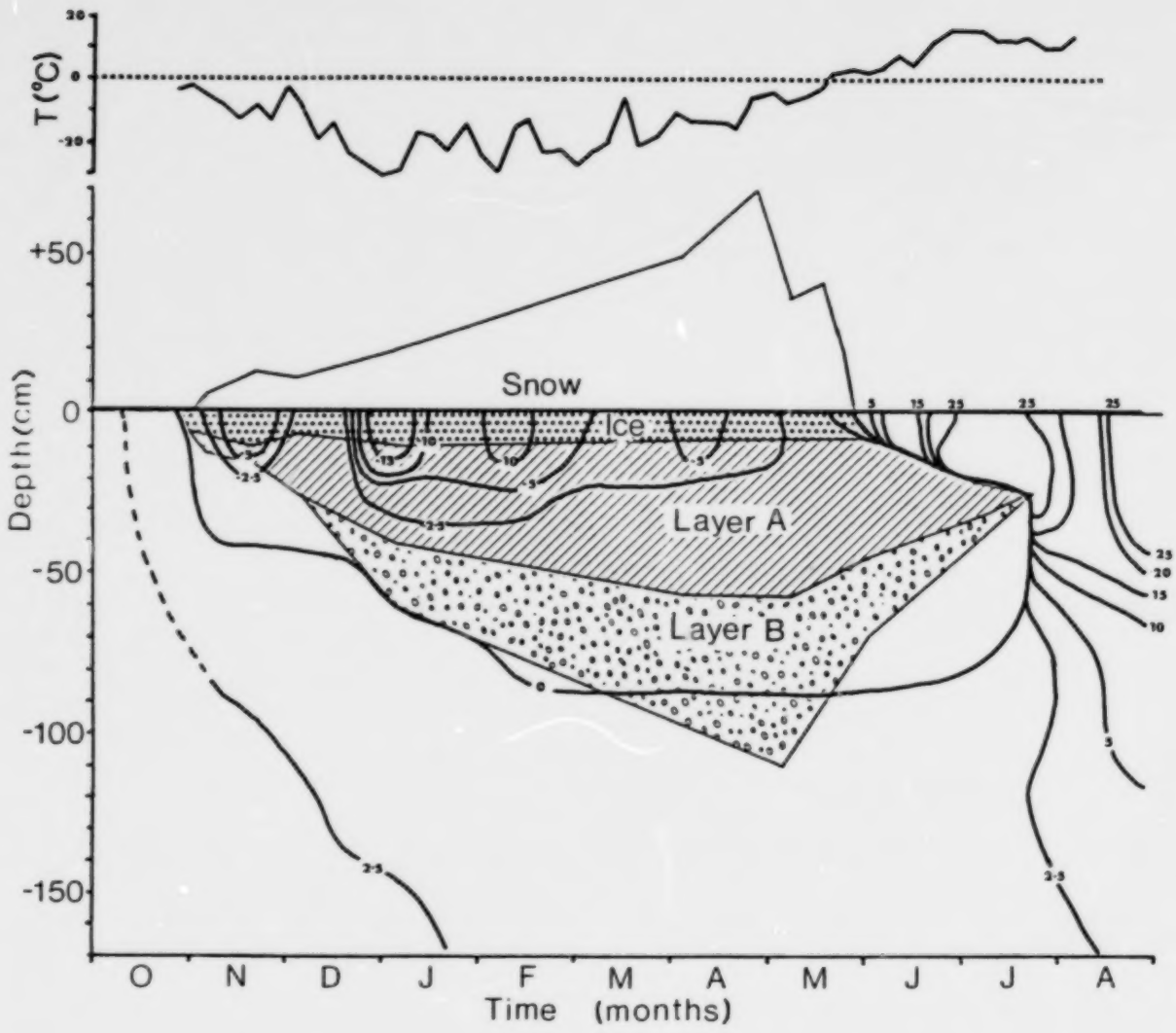


Figure 4. Layer A thaw depths, for Aries fen indicating surface (A) and below (B) melt.

According to Price (1983b) the hydrology of a mire can enhance the depth of freeze of a peatland. Juusela (1967) has shown that a dehydrated layer does naturally form under the freezing peat and exhibits an increased dehydrated layer when the water table is lowered by ditching. Layer B had a minimal growth rate until December. The rate of freeze then increased to 7.1 mm per day, coinciding with a lowering of the water table. The rate gradually reduced down to 0.6 mm per day, with a total freeze depth of 33.0 cm being noted. Overall, the fluctuations in growth rates for layer B were strongly related to the water table and the 0°C isotherm location, rather than other environmental conditions, after the initial growth period.

One of the limitations of using a set temperature profile is that the precise location(s) of isotherms can not be directly determined. Only general trends can be noted, such as the downward surface melt for the fen (Fig. 2). FitzGibbon (1981) suggested that thawing from beneath along with the surface melt occurred in peatlands containing seasonally frozen peat. Physical measurements of the frozen peat in Aries fen, showed that melt did occur from both above and below in mires. For the study year, the surface thaw rate for layer A (2.9 mm per day) was lower than the beneath rate of 4.3 mm per day. FitzGibbon (1981) experienced a dry spring in his study, and indicated that the lower thaw rates (Table 3) were caused by the thermal properties of the dry peat, reducing the heat flow from the surface to the frozen peat. This may explain the lower surface thaw rate for Aries, since June was a dry month (1.6 S.D. below the mean) and a 10–20 cm dehydrated peat layer was observed above the ice lens.

The thaw rates for layers A and B from beneath were similar (Table 2) suggesting that the same physical thaw mechanisms affected both. Melt from below could be caused by an upward heat flow into a steadily warming frozen peat layer. By combining the below thaw rate from layers A and B, a value of

8.5 mm per day was obtained. The combined thaw rate was about 3 times faster than the surface rate. This indicates the importance of thaw from beneath in seasonally frozen peat, during a dry spring.

Acknowledgments

This research project was supported by grants from the Department of Indian Affairs and Northern Development and the Natural Sciences and Engineering Research Council of Canada. The project was carried out from the McGill Subarctic Research Station in Schefferville, Quebec, and the authors would like to thank the following persons for their aid in the study: A Westcott, C.A. Nadeau, R. Shaw, O. Choulik, M.G.T. Sharpe, D.R. Barr, and D.T. Desrochers for his comments on the manuscript.

References

Barr, D.R. and Wright, R.C. 1981. Selected climatological data, 1955–1980 for the Schefferville (A) station. McGill Subarctic Research Paper, 32, pp. 117–134.

Brown, R.J.E. 1970. Occurrence of permafrost in Canadian peatlands. Proceedings of the 3rd International Peat Congress, Quebec, 1968, pp. 174–181.

_____ and Williams, G.P. 1972. The freezing of peatland. Building Research, National Research Council of Canada, Technical paper, 381, NRC 12281, 29 pp.

Cowell, D.W., Jeglum, J.K. and Merrian, J.C. 1978. Preservation of seasonal frost in peatlands, Kinoje lakes, southern Hudson Bay Lowland. 3rd International Conference on Permafrost, Edmonton, Alta., July, 1978, pp. 453–459.

Eurola, S. 1975. Snow and ground frost conditions of some Finnish mire types. Annales Botanici Fennici, 12, pp. 1–16.

FitzGibbon, J.E. 1981. Thawing of seasonally frozen ground in organic terrain in central Saskatchewan. Canadian Journal of Earth Science, 18(9), pp. 1492–1496.

Hoekstra, P. 1966. Moisture movements in soils under temperature gradients with the cold-side temperature below freezing. Water Resources Research, 2(2), pp. 241–250.

Ingram, H.A.P. 1983. Hydrology. In Gore, A.J.P. (ed) Mires: swamp, bog, fen and moor, vol. A. Elsevier, Amsterdam, pp. 67–159.

Jumikis, A.R. 1977. Thermal Geotechnics. New Brunswick, N.J., Rutgers University Press, 922 pp.

Juusela, T. 1967. Some results of field observations on the frost phenomenon on peat soil. Journal of Hydrology, 5, pp. 269–278.

Kingsbury, C.M. in press. Comparison of winter cover components for a subarctic lake and peatlands. Proceedings of the Eastern Snow Conference, vol. 31, 43rd annual meeting, Hanover, N.H., June 4–6, 1986.

_____ in prep. Nutrient leaching into subarctic peatlands. M.Sc. thesis, Department of Geography, McGill University, Montreal, Quebec.

Moore, T.R. unpublished manuscript. The thermal regime of peatlands in subarctic eastern Canada. Department of Geography, McGill University, Montreal, Quebec, 20 pp.

Pavlova, K.K. 1970. Phase composition of water and thermophysical characteristics of frozen peat in the study of infiltration. Transactions of the State Hydrologic Institute, 182, pp. 138–159. In: Soviet Hydrology, 4, pp. 361–378.

Penner, E. 1972. Soil moisture redistribution by ice lensing in freezing soils: Proceedings of the 17th annual meeting. Canadian Society of Soil Science. Lethbridge, Alta. July 4–8, 1971, pp. 44–62.

Price, J.S. 1983a. Winter freezing processes and hydrology of a complex mineral-organic watershed. Unpublished M.Sc. thesis, Department of Civil Engineering, University of Saskatchewan, Saskatoon, 107 pp.

_____ 1983b. The effect of hydrology on ground freezing in a watershed with organic terrain. 4th International Conference on Permafrost, Anchorage, Alaska, July 17–22, 1983, pp. 1009–1014.

Ryden, B.E. and Kostov, L. 1977. Groundwater and the waterfrost cycle in a tundra mire. Striae, 4, pp. 17–19.

_____ . 1980. Thawing and freezing in tundra soils. In Sonesson, M. (ed) Ecology of a Subarctic Mire. Ecological Bulletins (Stockholm) 30, pp 251–281.

Schumskii, P.A. 1964. Principles of structural glaciology: The petrography of fresh-water ice as a method of glaciological investigation. Dover Pub., Inc., New York, 497 pp.

Sjörs, H. 1950. On the relation between vegetation and electrolytes in north Swedish mire water. Oikos, 2(2), pp. 241–258.

Sonesson, M. 1969. Studies on mire vegetation in the Tornetrask area, Northern Sweden. II Winter conditions of the poor mires. Botaniska Notiser, 122, pp. 481–511.

Thom, B.C. 1972. The role of spring thaw in string bog genesis. Arctic, 25, pp. 236–239.

Zoltai, S.C. and Pollett, F.C. 1983. Wetlands in Canada: their classification, distribution and use. In Gore, A.J.P. (ed) Mires: swamp, bog fen and moor, vol. B. Elsevier, Amsterdam, pp. 245–268.

GLACIATION LOCALE PENDANT LE PLÉISTOCÈNE SUPÉRIEUR ET L'HOLOCÈNE DANS LA CHAÎNE RUBY, AU SUD-OUEST DU TERRITOIRE DU YUKON

Diane Lacasse et Peter Johnson

Département de géographie, Université d'Ottawa, Ottawa, Ontario K1N 6N5

Niveau: D. Lacasse, Maîtrise

Résumé

Depuis la fin de la dernière glaciation du Pléistocène les fronts des glaciers du sud-ouest du Yukon ont fluctué à diverses périodes. Une chronologie relative des fluctuations glaciaires peut être établie par la datation des dépôts moraniques laissés par les glaciers de cirque de la chaîne Ruby. Compte tenu de la position géographique et des caractéristiques climatiques actuelles, la présence de glaciers de cirque au sein de cette chaîne et leurs fluctuations durant l'Holocène nécessitent des conditions paléoclimatiques différentes de celles d'aujourd'hui.

Selon des divers résultats obtenus, on peut déceler au moins trois réavancées glaciaires qui datent d'avant 1200 ans BP. Ces réavancées n'ont pas été nécessairement synchronisées d'un cirque à l'autre. Le problème reste à déterminer si ces glaciers datent de la fin du Pléistocène ou de l'Holocène.

Les moraines de trois cirques d'orientation et d'altitude semblables ont été échantillonnées. De façon relative, une chronologie des multifluctuations glaciaires de la chaîne Ruby a été établie en déterminant l'âge des moraines. Le degré de développement de la végétation, du sol et du lichen Rhizocarpon geographicum s1 ainsi que la téphrochronologie nous ont permis d'établir cette chronologie partielle. La plupart des moraines étudiées semblent dater de la fin du Pléistocène. Par contre on trouve d'énormes plaques de neige semi-permanentes nichées entre la moraine et le versant à l'intérieur de l'un des cirques. Sur cette moraine, certaines caractéristiques des facteurs étudiés et mentionnés ci-dessus

sont moins développées qu'ailleurs. Ceci porte à croire que cette moraine aurait été édifiée au début de l'Holocène.

Mots-clés: Multifluctuations, glaciers de l'Holocène, Chaîne Ruby, Sud-ouest Yukon.

Abstract

Since the end of the last glaciation of the Pleistocene, the glacier fronts in the south-western Yukon have fluctuated at various times. A relative chronology of glacier fluctuation can be established by dating the till deposited by the cirque glaciers of the Ruby Range. Given the geographical position and the present climatic characteristics, the presence of cirque glaciers in this range and their fluctuations during the Holocene must mean that palaeoclimatic conditions were different from those of today.

Results obtained indicate at least three glacial readvances occurring earlier than 1200 years BP. These readvances were not necessarily synchronized from one cirque to the next. The problem is to determine whether these glaciers date from the end of the Pleistocene or from the Holocene.

Samples were taken from the moraines of three cirques of similar orientation and altitude. By determining the age of the moraines a relative chronology of the multiple glacial fluctuations of the Ruby Range was established. We were able to draw up this partial chronology using the degree of development of the vegetation, the soil and the lichen Rhizocarpon geographicum sl, and from the tephrochronology. Most of the moraines examined appear to date from the end of the Pleistocene. In one of the cirques, however, there are huge semi-permanent snow masses lodged between the moraine and the interior slope. On this moraine certain characteristics of the factors studied and mentioned above are less developed than in other locations. This suggests that the moraine in question may have come into existence at the beginning of the Holocene.

Key words: Multifluctuations; Holocene glaciers; Ruby Range; south-western Yukon.

Introduction

Depuis le début du siècle, nos connaissances concernant les fluctuations climatiques et les positions de fronts glaciaires ont bien évolué. Les géoscientifiques ont étudié le comportement des glaciers et tenté d'établir une chronologie de leur histoire. Il y a eu des époques glaciaires et interglaciaires, chacune d'elles marquées par des fluctuations importantes.

Au cours du Pléistocène, le sud-ouest du Yukon fut envahi par au moins trois glaciations (Denton, 1974). La première, la glaciation de Shakwak, fut suivie de l'interglaciaire Silver. Il y a 49000 ans C-14 BP (y-1486), une deuxième phase glaciaire prit place, la glaciation Icefield, suivie de l'interstade Boutillier (Denton, 1974). Enfin, le stade glaciaire le plus récent, entre 29600 $\pm$ 460 ans C-14 BP (GSC-769) et 12500$\pm$ 200 ans C-14 BP (Y-1386), se nomme Kluane-Macauley (Denton, 1974). Depuis environ 12000 ans BP, cette dernière glaciation a fait place à la phase interglaciaire actuelle. Cet interglaciaire est cependant divisé en plusieurs stades et interstades. Tout d'abord, suivant la glaciation de Macauley, l'interstade Hypsithermique, caractérisée par des températures plus chaudes, durera jusqu'à environ 5800 ans BP (Denton et Karlén, 1973). Ensuite, des stades plus froids résultent en des réavancées, d'importance variable, des fronts glaciaires. Selon Denton et Karlén (1973 et 1977), le front des glaciers aurait avancé entre 5800 et 4900 ans BP, 3300 et 2400 ans BP, 1250 et 1050 ans BP et pendant le Petit Age Glaciaire (*sensu stricto*). Aujourd'hui, il n'y a plus de glace dans la chaîne Ruby. On ne retrouve que les dépôts que nous ont légués les glaciers.

Basé sur cet héritage géomorphologique, la présente recherche a pour but d'établir une chronologie des fluctuations des glaciers de cirque dans la chaîne Ruby, au sud-ouest du Yukon. Dans un deuxième temps, elle vise à vérifier si ces glaciers de cirque existaient durant l'Holocène et de déterminer les implications paléoclimatiques de ces fluctuations glaciaires.

Description de la region étudiée

La chaîne Ruby, s'étendant au nord-est du lac Kluane, offre un paysage découpé de vallées et de plateaux situés entre environ 1200 m à 2000 m d'altitude. Le travail s'est effectué dans trois cirques situés plus précisément entre les rivières Raft et Talbot entre 61° 30′ et 61° 34′ de latitude nord et entre 138° 10′ et 138° 20′ de longitude ouest (Kluane Lake, 115G et F, Ed. 1 Ase série A 502). Les trois cirques échantillonnés sont d'orientation et d'élévation semblables; deux sont d'orientation nord, un, nord-ouest. Ils s'élèvent respectivement à 1450 m, 1750 m et 1780 m d'altitude.

Bien que sise près des côtes du Pacifique, toute la région à l'est des Monts St-Elias, dont la chaîne Ruby, trouve son climat «continentalisé». La barrière que forment les Monts St-Elias bloque les masses d'air humide, les obligeant à prendre de l'altitude, ce qui résulte en la perte de la majeur partie de leur humidité sur le flanc ouest de ces montagnes (Webber, 1974). En plus, en hiver, toute la région baigne dans l'air arctique froid et sec venant de la mer de Beaufort couverte de glace (Kendrew et Kerr, 1955). Les températures sont basses et les précipitations faibles. Dans les cirques et les vallées la différence de température de deux masses d'air engendre des vents catabatiques. En été, réchauffé par le soleil, l'air chaud monte et l'air frais, plus dense, descend dans les cirques et les vallées. Ce vent froid assèche et maintient des températures fraiches dans le sol.

La végétation recouvrant le sol des cirques étudiés est, selon l'altitude, de type toundra arbustive ou herbacée. Sur les surfaces les plus mal drainées, le sol est colonisé par des mousses (Ex.*sphagnum*). Sur le matériel mieux drainé, comme le matériel glaciaire et fluvioglaciaire, s'installent les plantes de type *dryas, gramineae* ainsi que les lichens. Suivant les cours d'eau, où le sol est plus humide, grandissent les *bétulas* et les *salix*. La région étudiée située au-dessus de la limite des arbres, on rencontre peu de picea.

Dans la chaîne Ruby, le pergélisol discontinu recouvre le sol. Les basses températures engendrent un substratum gelé et imperméable affectant directement le développement du sol. A ces endroits, le mollisol cryoturbé est souvent humide, froid et mal drainé. Parfois, on trouve des lentilles de glace enfouies dans le sol. Le mollisol dont l'épaisseur est d'environ de 30 cm est recouvert d'une couche de matière organique peu ou mal décomposée, épaisse de 2 à 3 cm environ. Le matériel parental sur lequel ces sols se développent est principalement formé de matériel glaciaire, fluvioglaciaire ou de colluvions. La cendre volcanique, «White

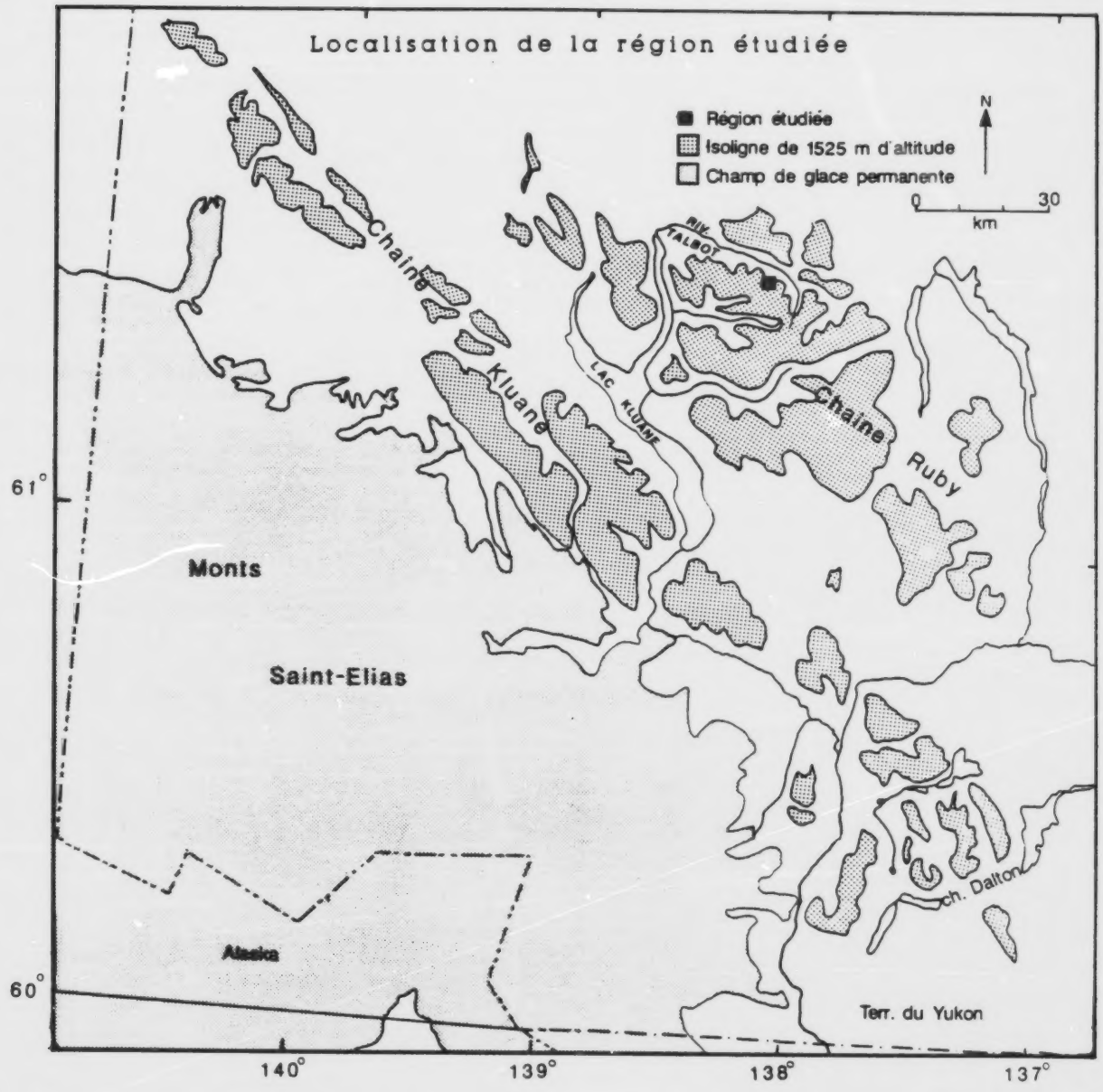


Figure 1. Carte de localisation de la région étudiée.

River Ash» se retrouve soit en couche distincte, soit mélangée au reste du matériel. Cette cendre volcanique date d'environ 1255 ± 90 ans BP (I-6231) (Denton et Karlen, 1977).

Au point de vue géologique, la chaîne Ruby est composée d'un batholithe granitique intrusif (Bostock, 1948, Muller, 1967). Ce batholithe est composé principalement de granodiorite à l'hornblend-biotite et de quartz diorite.

Méthodologie

Dans le cadre d'une étude des multifluctuations glaciaires d'une région, la rareté matériel pouvant donner des âges absolus, force le chercheur à opter pour une chronologie relative. Selon Birkeland (1973), les indications les plus crédibles apportées par des datations relatives découlent de l'emploi combiné de différentes méthodes. Au sein de la région étudiée, la comparaison des résultats obtenus par l'ensemble des différentes méthodes de datation présente des caractéristiques temporelles plus justes que les résultats découlant d'une seule source. La concordance des diverses données justifie davantage les résultats obtenus.

Notre étude s'appuie principalement sur trois types de méthodes de datation relative: la lichénométrie, la succession du développement de la végétation implantée sur chaque

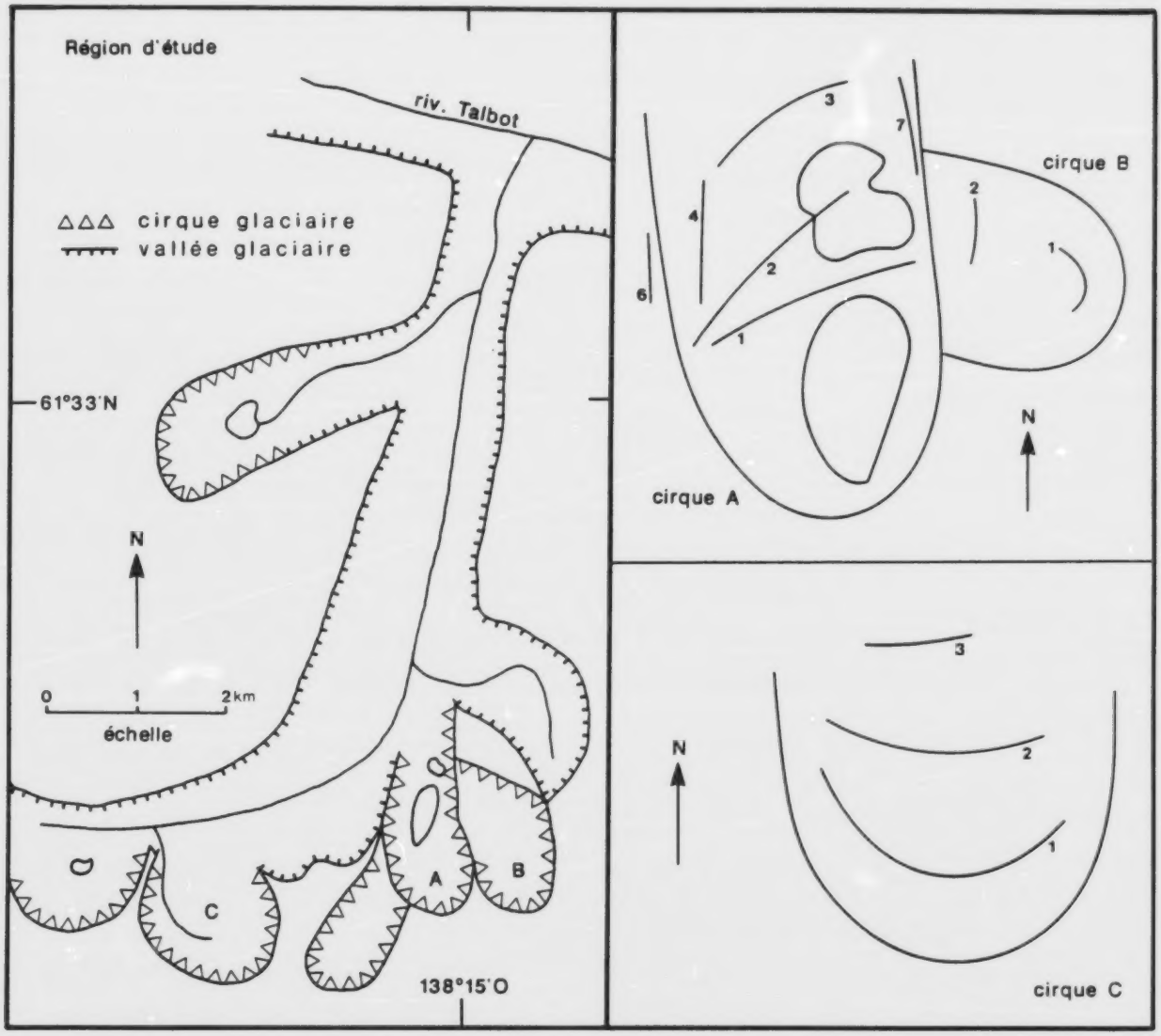


Figure 2. Schéma de la position des moraines dans les cirques.

moraine étudiée et le degré de développement des sols. Pour rendre les résultats comparables, l'échantillonnage a été effectué dans des conditions lithologiques, topographiques et de micro-climat semblables.

Lichénométrie

Le choix de l'espèce de lichen utilisée s'est arrêté sur les *Rhizocarpon geographicum s1.* vu l'abondance de sa présence ainsi que ses caractéristiques visuelles et physiologiques. En effet, au cours de ses études sur l'île de Baffin, Miller (1973) affirme que le lichen *Rhizocarpon geographicum (L.) DC* fait partie du groupe des premières espèces colonisatrices et possède un taux lent de croissance. Cette espèce est l'une des plus utiles pour l'étude des dépôts mis en place au cours des 5000 dernières années dans les régions arctiques subissant des conditions de températures et d'humidité difficiles.

L'échantillonnage des thalles du lichen *Rhizocarpon geographicum s1.* s'est effectué sur un transect couvrant toute la longueur de la crête morainique. Nous avons tout d'abord mesuré les individus les plus circulaires possédant les plus grands diamètres au 0.5 mm près en nous servant d'un ruban à mesurer. Sur chacune des moraines, plusieurs individus ont été mesurés afin d'éviter de se trouver en présence d'un thalle possédant une grosseur extrême engendrée par quelques phénomènes externes irréguliers. En complément, nous avons aussi estimé visuellement le pourcentage de recouvrement des blocs par les lichens. L'utilisation de cette donnée

réduit aussi la possibilité d'erreur introduite par la présence d'individus anormalement grands (Matthews, 1973).

Pédogénèse

Sur le dessus de la crête de chaque moraine étudiée, des échantillons de sol ont été prélevés. Chaque section de sol a été décrite selon les caractéristiques visuelles suivantes: profondeur du profil et épaisseur de chacun des horizons, couleur évaluée selon la charte Munssell, texture, pierrosité, structure et une estimation du degré de cohésion.

Dans les régions nordiques, les processus physiques interviennent avec la succession des cycles gel-dégel, fractionnant les blocs et les cailloux jusqu'à la taille des limons et des argiles. Selon Viereck (1966), le pourcentage des particules sableuses diminue au profit des particules plus fines dans les horizons supérieurs à mesure que le sol se développe à cause de la plus grande efficacité des agents d'altération à la surface. On a donc calculé le pourcentage des différentes grosseurs de particules en tamisant les échantillons d'abord traités au peroxyde d'hydrogène pour éliminer la matière organique présente et à une solution d'hexamétaphosphate de sodium comme défloculant. Puis nous avons porté les résultats obtenus sur une courbe cumulative.

Différentes études ont démontré que le pH du sol diminue avec l'âge dans l'horizon composé de matériel minéral. Par exemple, sur les moraines du glacier Klutlan, Jacobson et Birks (1980) ont noté que le pH passe de 8.0 pour un sol appartenant à la moraine la plus jeune à 5.5 et 6.5 pour les sols des moraines les plus agées. Utilisant de l'eau distillée comme extractant, le pH des sols étudiés a été mesuré au pHmètre.

Un des aspects importants de la formation d'un sol est l'addition de matériel organique (Viereck, 1966). Dans les sols arctiques, on décèle une production faible mais certaine de matière organique qui se dégrade extrêmement lentement. Avec le temps, dans les horizons supérieurs, le matériel organique s'accumule plus rapidement qu'il se décompose, favorisant le développement de sols avec un horizon organique (Viereck, 1966). Par calcination, on a calculé le pourcentage de matière organique contenu dans chacun des niveaux de sol.

On s'est aussi interessé au taux de fer et d'aluminium libérés par l'altération des argiles en supposant qu'après extraction, moins on retrouverait d'ions fer et aluminium dans notre solution, plus les argiles auraient été altérées, et plus de fer et d'aluminium auraient été libérés et emportés par lessivage dans les horizons inférieurs. Comme technique de datation, selon Evans (1985), on peut utiliser le rapport entre le taux d'oxyde de fer amorphe et celui de l'oxide de fer cristallin. Initiallement, l'oxyde de fer est amorphe mais par altération, il prend la forme cristalline. Ce rapport est calculé en déterminant le taux de fer amorphe extrait par une solution d'oxalate d'ammonium et celui du fer de forme cristalline extrait par une solution de dithionite-citrate-bicarbonate-DCB. Ces extractions ont été effectuées selon les méthodes décrites par McKeague (1971). On a aussi utilisé le rapport Al/Fe extrait au DCB car selon Evans (1985), ce rapport s'accroît avec l'âge du sol.

Pour évaluer la concentration de fer et d'aluminium libérés par les argiles altérées, nous avons aussi calculé le taux de fer et d'aluminium extraits par une solution d'oxalate d'ammonium par rapport à la concentration des ions fer et aluminium libérés par une extraction totale aux acides perchlorique, fluorique et chloridique.

Développement de la végétation

Suivant le retrait de la glace, une végétation colonisatrice comme les mousses, les lichens et quelques plantes vasculaires fixatrices d'azote, s'est implantée sur les moraines dénudées. Avec le temps, le couvert végétal s'est diversifié et sa densité s'est accrue. Les changements au niveau de la population végétale sont fonction du temps et sont fortement reliés aux changements de certaines propriétés du sol comme le pourcentage de matière organique de l'horizon supérieur et le taux d'azote (Mahaney, 1973). Ce développement varie aussi selon le taux de croissance des différentes espèces, leur longévité et leur capacité d'adaptation aux propriétés physiques et chimiques du sol (Crocker et Dickson, 1957).

Dans un quadrat de 1 m^2, renfermant toutes les espèces appartenant à la communauté (Meuller-Dombois et Ellenberg, 1974), nous avons cueilli un spécimen de chaque espèce présente pour en faire l'identification en laboratoire à l'aide d'une Flore (Hulten, 1968). Puis, nous avons évalué le pourcentage de recouvrement par les groupes d'espèces présentes ainsi que le recouvrement des moraines par l'ensemble de la végétation.

Résultats

Lichénomètrie

Dans les trois cirques étudiés, 100% des roches sises sur les moraines étaient couvertes par des lichens de toutes sortes. Cependant, selon les moraines, le pourcentage de recouvrement des roches variait. D'une moraine à l'autre, 60 à 95% de la surface des blocs était couverte de lichens de différentes espèces. Dans le cirque A, les moraines dont les blocs possèdent le plus haut degré de recouvrement par les différents lichens sont les nos. 7, 4 et 2. Dans le cirque B, la moraine no 1 est la moins couverte et diffère de la no 2. Dans le cirque C, la no 1 est la plus couverte. Ensuite c'est la no 3. On note aussi que le recouvrement des blocs par les lichens est beaucoup moins dense dans le cirque C que dans les autres.

De son côté, le lichen *Rhizocarpon geographicum s1.* représente généralement 50% de tous les lichens. Dans le cirque C, les moraines 2 et 3 sont les plus couvertes avec 55 et 59% et la no 1, la moins couverte, avec 33%. Dans le cirque B, il y a une légère différence de recouvrement; No 2 avec 53% de recouvrement et 45% pour la moraine no 1. Dans le cirque A, le lichen *Rhizocarpon geographicum s1.* recouvre d'avantage les moraines nos 3 et 6 et moins les nos 1 et 7. Le thalle le plus grand et le plus circulaire est de même grandeur sur toutes les moraines du cirque B. Il est plus grand sur les moraines 7 et 4 du cirque A.

Selon les résultats de la lichénométrie, on remarque une différence entre les deux moraines du cirque B. Dans le cirque C, les moraines 2 et 3 donnent des résultats semblables. Les blocs de la moraine no 1 montrent cependant une petite différence. Les caractéristiques de la présence des lichens y sont moins développées. Dans le cirque A, les résultats sont contradictoires. Selon le type de mesure, tantôt c'est la moraine

TABLE 1
Résultats

		A 1	A 2	A 3	A 4	A 6	A 7	B 1	B 2	C 1	C 2	C 3
FeO/FeD	'*	0.56	0.34	0.94	0.67	1.83	0.99	0.56	0.48	0.60	0.62	0.40
	"	0.42	0.39	0.95	0.64	2.0	0.61	0.66	0.60	0.39	0.54	0.29
AlD/FeD	'	0.28	0.12	0.02	0.30	0.06	0.06	0.09	0.12	0.42	0.10	0.10
	"	0.32	0.17	0.09	0.32	0.13	0.12	0.15	0.32	0.23	0.18	0.15
FeO/FeT	'	0.21	0.19	0.11	0.24	0.12	0.14	0.20	0.18	0.19	0.16	0.16
	"	0.21	0.20	0.14	0.27	0.20	0.18	0.22	0.16	0.12	0.20	0.13
AlO/AlT	'	0.07	0.04	0.01	0.07	0.02	0.01	0.03	0.04	0.07	0.02	0.03
	"	0.08	0.04	0.01	0.09	0.01	0.04	0.04	0.13	0.10	0.05	0.04
épaisseur du profil (cm)		36.5	32	38	37.5	21	37	16	38	27	25	22
nombre d'horizons		3	2	1	2	2	3	1	4	2	1	1
cm sous la cendre volcanique		29					29		33	18.5		
épaisseur de l'horizon organique (cm)		1.0	1.5	0.5	1.0	0.5	1.0	3.0	2.5	3.0	2.0	3.0
% de matière organique		6.55	5.98	3.73	8.15	10.53	5.43	10.15	27.4[illegible]	32.57	9.7[illegible]	12.39
pH	'	6.24	6.40	6.32	6.66	6.40	6.32	4.64	4.5[illegible]	6.62	4.5[illegible]	5.26
	"	5.04	6.38	6.22	6.16	6.38	6.28	4.62	5.3[illegible]	6.23	4.5[illegible]	5.18
granulométrie % <53μ	'	7.0	28.0	6.0	20.0	25.0	18.0	32.0	28.0	27.0	75.0	24.0
	"	15.0	42.0	6.0	28.0	25.0	18.0	32.0	95.0	25.0	75.0	47.0
% de recouvrement par toutes les espèces de lichens		85	90	80	95	60	95	55	75	60	85	70
% de recouvrement par les Rhizocarpon geographicum sl.		46	55	87	63	66	31	45	53	33	58	59
Rhizocarpon geographicum le plus grand et le plus circulaire (cm)		9.4 9.5 9.8	8.2 8.2 8.3	5.0 5.2 5.3	9.1 9.9 8.7	8.0 8.7 8.8	13.5 13.5 15.2	9.7 9.8 9.8	9.5 8.7 9.6	7.6 7.6 7.9	6.3 7.6 7.7	7.2 7.7 8.4
grosseur moyenne des thalles de Rhizocarpon geographicum sl. (cm)		6.0	5.0	2.5	5.0	3.0	5.0	plaques 6.0		plaques 5.0		4.0

* ' échantillon pris au-dessus de la couche de cendre volcanique
" échantillon pris au-dessous de la couche de cendre volcanique

no 7 qui serait la plus vieille et la no 3 la plus jeune, parfois, c'est l'inverse. Il en va de même pour la no 6.

Pédogénèse

En général, le profil pédologique démontre des développements semblables dans le cirque A au point de vue profondeur et nombre d'horizons. Dans le cirque C, ces caractéristiques semblent moins développées que dans A. Enfin, dans le cirque B, on dénote une différence marquée entre les moraines 1 et 2.

Le pH diminue généralement avec la profondeur. Dans le cirque B, on retrouve des pH plus bas ainsi qu'une couche de matière organique plus épaisse à la surface. Selon les études citées ci-dessus (Jacobson et Birks, 1980, Viereck, 1966), le pH diminue avec l'âge. Mais, dans ce cas, l'inverse se présente. Est-il possible que le fait que certaines moraines, où les conditions de températures sont plus basses et où le pergélisol est présent, possèdent un couche de matière organique qui s'accumule car elle se décompose mal, et que cette matière organique mal décomposée acidifie le sol, engendrant ainsi un pH plus faible même sur les moraines plus jeunes?

Aussi, les rapports FeO/FeD, AlD/FeD, AlO/AlT et FeO/FeT offrent sensiblement les mêmes résultats que les autres méthodes employées. Dans le cirque C, les résultats diffèrent d'une rapport à l'autre. Dans le cirque B, on dénote encore la même différence entre les moraines 1 et 2. Enfin, dans le cirque A, les moraines les plus âgées seraient 1 et 4 tandis que les plus jeunes seraient 3, 6 et 7.

Succession de la végétation

Le développement de la végétation implantée sur les moraines étudiées révèle les mêmes résultats que ceux obtenus par les autres méthodes de datation utilisées. Dans le cirque A, les espèces représentées, ainsi que la proportion qu'elles occupent sur les moraines nos 1, 2 et 3, sont semblables. De plus, sur ces moraines, on trouve des plaques dispersées occupant des dépressions peu profondes et couvertes de bouleaux et de saules. Ceci révèle la présence de plaques de neige qui, à la fonte du printemps, apportent l'eau qui s'emmagasine dans ces dépressions et aide à la croissance de ces deux espèces. Par contre, sur la moraine no 6, une plus forte proportion de graminés indique un sol plus humide surtout dans les micro-dépressions mesurant quelques centimètres de diamètre. L'eau, ne pouvant pas s'infiltrer dans le pergélisol, reste dans le mollisol et fournit ainsi l'humidité nécessaire à la croissance des graminés.

Dans le cirque B, la végétation démontre un microclimat beaucoup plus sec. On remarque aussi que par rapport à toutes les moraines étudiées dans les trois cirques, la végétation implantée sur la moraine no 1 du cirque B est la moins développée. La végétation qui la couvre est fortement dominée par les dryas et les lichens accompagnés de quelques carex. Enfin, dans le cirque C, le développement de la végétation présente est sensiblement la même que celle du cirque A.

Discussion

Selon le nombre de moraines et la position qu'elles occupent dans chacun des cirques, on peut déceler au moins trois positions frontales (fig. 2). On remarquera trois moraines dans le cirque C, deux dans B et 6 dans A. Logiquement, leur position indique la chronologie de leur édification. Dans le cirque C, la moraine no 3 se serait édifiée la première, ensuite la no 2 et la no 1. Dans le cirque B, la moraine no 2 serait la plus vieille et 1 la plus jeune. Enfin, dans le cirque A, 6, 3 et 7 les plus vieilles, ensuite 4, 2 puis no 1 la plus jeune.

Selon les résultats fournis par les différentes méthodes de datation utilisées, dans le cirque B, on dénote une différence nette entre le degré de développement des facteurs étudiés sur les deux moraines présentes. La moraine no 1 est nettement plus jeune que la no 2. Dans le cirque C, la moraine no 1 présente en général des caractéristiques moins développées. Il en va de même pour la moraine no 3, où on s'attendrait à découvrir des caractéristiques de développement plus avancé. Enfin, c'est dans le cirque A que le degré de développement des facteurs est le plus variable et le plus discordant par rapport à la position des moraines. On note une différence entre les moraines no 6, 7 et 3. En plus, sur ces moraines, le degré de développement est moins avancé que celui des moraines no 1 et 2 qui, selon leur position dans le cirque, devraient s'être édifiées plus tard.

Ces différences dans le développement sont peut-être causées par divers facteurs externes. Par exemple, le développement des caractères étudiés de la moraine 6 du cirque A aurait peut-être été freiné par la présence de neige permanente, par des conditions de pergélisol ou d'ensoleillement moins propices au dégel. Dans ce même cirque, la moraine 3, plus près de la sortie du cirque et composée d'une forte proportion de cendre volcanique, probablement apportée par le vent, offre des conditions moins propices au développement du sol et de la végétation.

Enfin, la moraine no 3 du cirque C, située directement dans la vallée passant au pied du cirque, est beaucoup plus petite que toutes les autres moraines étudiées. Elle a probablement subi une forte érosion par les eaux fluvioglaciaires diminuant considérablement sa dimension. Cette érosion pourrait être la cause du rajeunissement des caractéristiques de cette moraine par rapport aux autres situées plus en amont dans le cirque.

La position des moraines dans les cirques et les résultats obtenus par les diverses méthodes employées démontrent que le développement des sols, de la végétation ainsi que des lichens ne s'est pas amorcé immédiatement après l'édification de la moraine. Il semble y avoir eu un certain laps de temps avant que le développement commence. Des facteurs externes comme la présence du pergélisol, l'érosion et l'accumulation de neige en congères permanentes et semi-permanentes ont agi. Celles-ci ne semblent pas avoir agi en même temps ou durant une même période de temps, faisant varier d'une moraine à l'autre le laps de temps écoulé entre l'édification de la moraine et la formation de son sol.

Sans datation au radiocarbone, les résultats obtenus par les méthodes de datation relative employées ne peuvent servir à élaborer une chronologie absolue des fluctuations des glaciers. Même si les échantillons ont été prélevés dans des conditions les plus semblables possible, les résultats sont fortement affectés par de nombreux facteurs dont l'importance relative ne peut être déterminée. La cendre volcanique datée à environ 1255 ± 90 ans BP ((I-6231), (Denton et

Karlén, 1977)) et présente dans tous les profils de sol prélevés sur les moraines indique que leur édification est nécessairement antérieure à cette date.

Implications paléoclimatiques

Dans une étude sur les glaciers, les conditions d'humidité et de température sont les deux données essentielles. Ce sont elles qui règlent l'accumulation et l'ablation (Paterson, 1981), donc la survie ou la destruction des glaciers. Dans la chaîne Ruby, où les chutes de neige ne sont jamais très grandes (Normales climatiques au Canada), la vie des glaciers sera régie essentiellement par des basses températures qui en été freinent l'ablation. Ainsi, dans cette chaîne, on trouve une très faible accumulation accompagnée d'une plus ou moins forte ablation défavorisant la survie des glaciers.

Par sa position géographique, pendant le Pléistocène comme l'Holocène, cette région n'a jamais été favorisée par de fortes précipitations (Lagarec, comme. pers.). Le maintien de glaciers dans cette région s'effectuerait par la faible ablation au cours de l'été. Cette caractéristique impliquerait une circulation des masses d'air plus zonale en été (venant de l'ouest plutôt que du sud) donnant des températures plus fraîches durant cette saison (Andrew *et al.*, 1972, Lagarec, comm. pers.). Aujourd'hui, en été, les masses d'air viennent du sud (Weatherwise, p. 175, 207, 219, etc.) apportant ainsi de la chaleur. En fait, avec des températures plus fraîches en été, on aurait plus de chances de pouvoir trouver de petits glaciers dans la chaîne Ruby.

Une petite fluctuation de température ne serait sans doute pas suffisante pour faire naître des glaciers dans la chaîne Ruby. On ne pourrait avoir que des bancs de neige permanents ou des débuts de névéification. Toutefois, il serait difficile de prouver la présence de glacierets ou de névés car ces deux phénomènes sont trop petits ou pas assez développés pour ériger des moraines témoins de leur existence. En plus, la naissance de nouveaux glaciers à partir de névés demanderait un trop grand bouleversement dans le type de circulation actuelle des masses d'air.

Dans les cirques étudiés, s'il y a eu la présence de glaciers durant l'Holocène, se serait dans le cirque B. En effet, tous les résultats démontrent que la moraine 1B présente des caractéristiques moins développées qu'ailleurs. De plus, on retrouve d'énormes congères de neige semi-permanentes nichées entre cette moraine et la paroi du cirque. A cet endroit, s'il y a eu activité de la glace durant l'Holocène, selon les implications climatiques discutées plus haut, cela devrait probablement être une réactivation d'un restant de glace du Pléistocène ayant résisté jusqu-là. En supposant que ce restant de glace était protégé par une couche de débris, faisant face au nord-ouest et protégé du vent par la moraine, il aurait pu baigner dans un micro-climat favorable à sa survie. Cette réactivation aurait probablement eu lieu au début de l'Holocène, par exemple, lors de la première réavancée des fronts glaciaires proposée par Denton et Karlén (1973 et 1977). Ensuite, avec le temps, elle aurait diminuée jusqu'à sa dimension actuelle.

Conclusion

Dans le cadre d'une étude des fluctuations glaciaires et de l'élaboration d'une chronologie, le meilleur outil s'avère la datation au radiocarbone. Malheureusement, la difficulté de trouver du matériel datable situé dans des endroits pertinents nous incite à opter pour l'utilisation de méthodes de datation relative. Cependant, les résultats obtenus par de telles méthodes doivent être considérés avec soin.

À travers cette recherche, les résultats des techniques de datation relative employées ne permettent pas d'élaborer une chronologie des fluctuations glaciaires des cirques étudiés de la chaîne Ruby. On ne peut affirmer non plus que ces cirques ont été occupés par la glace durant l'Holocène. Cependant, la différence marquée dans le développement des facteurs étudiés de la moraine no 1 du cirque B n'exclut pas la possibilité de survie d'un petit glacier dans ce cirque durant l'Holocène.

Afin de donner du poids à cette hypothèse, il faudrait vérifier dans les autres cirques de la chaîne Ruby pour voir si on ne trouverait pas d'autres indices, conditions semblables ou plus marquées et même trouver du matériel datable au C-14.

Remerciements

Je tiens à exprimer mes sincères remerciements à mon directeur de thèse Dr. Peter G. Johnson et aux Professeurs Michel Phipps et Daniel Lagarec pour leur aide académique, Messieurs Richard Kodybka et John Loop pour leur aide très appréciée au laboratoire, au Conseil de recherches en sciences naturelles et en génie du Canada pour l'appui financier (dépenses courantes A-7486, Dr. P.G. Johnson), le Ministère des Affaires indiennes et du nord dans le cadre du programme de formation scientifique dans le nord et enfin l'Arctic Institute of North America pour leur aide logistique.

Références

Andrew, Barry, Bradley, Miller, William, (1972). "Past and present glaciological responses to climate in Eastern Baffin Island" in Quaternary Research, vol. 2, p. 303-314.

Barry, Roger G., (1981), Mountain Weather and Climate, Methuen and Co. Ltd., New York, p. 270-276.

Birkeland, Peter W., (1973), "Use of relative age-dating methods in a stratigraphic study of rock glacier deposits, Mt. Sopris, Colorado" in Arctic and Alpine Research, vol. 4, p. 401-416.

Birkeland, Peter W., (1978), "Soil development as an indication of relative age of quaternary deposits, Baffin Island, N.W.T., Canada" in Arctic and Alpine Research, vol. 10, no. 4, p. 733-747.

Bostock, H.S., (1948), "Physiography of the Canadian Cordillera with special reference to the area north of the fifty-fifth parallel", in Geological Survey of Canada, Memoir 247.

Crocker, R. and Dickson, B., (1957), "Soil development on the recessional moraines of the Herbert and Mendenhall glacier, S.E. Alaska" in Journal of Ecology, vol. 45, p. 169-185.

Denton, G.H. (1974), "Quarternary glaciation of the White River Valley, Alaska, with a regional synthesis for Northern St. Elias Mountains, Alaska and Yukon Territory" in Geological Society of America Bulletin, vol. 85, p. 871-892.

Denton, G.H., Karlen, W., (1973), "Holocene climatic variations — their pattern and possible cause" in Quarternary Research, vol. 3, p. 155-205.

Denton, G.H., Karlen, W. (1977), "Holocene glacial and tree-line variations in the White River Valley and Skolai Pass, Alaska and Yukon Territory" in Quaternary Research, vol. 7, p. 63-111.

Evans, L.J. (1985), "Dating methods of pleistocene deposits and their problems: VII. Paleosols" in Dating Methods of Pleistocene Deposits and Their Problems, reprinted with revisions from a series of papers in Geoscience Canada, 1978-1982 published by the Geological Association of Canada. Ed. by N.W. Rutter, Dept. of Geology, U. of Alberta, Edmonton, p. 53-59.

Hulten, E., (1968), Flora of Alaska and Neighboring Territories. A manual of the Vascular Plants. Stanford University Press, Stanford, California, 1008 pages.

Jacobson Jr., G.L., Birks, H.J.B., (1980), "Soil development on recent end moraines of the Klutlan Glacier, Yukon Territory, Canada" in Quaternary Research, vol. 14, p. 87–100.

Kendrew, W.G., Kerr, D., (1955), The Climate of British Columbia and the Yukon Territory. Edmond Cloutier, C.M.G., O.A., D.S.P., Ottawa, Queen's Printer and Controller of Stationery.

Mahaney, W.C., (1973), "Neoglacial chronology in the Fourth of July Cirque, Central Colorado Front Range" in Geological Society of America Bulletin, vol. 84, p. 161–170.

Matthews, J.A., (1973), "Lichen growth on an active medial moraine, Jotunheimen, Norway" in Journal of Glaciology, vol. 12, no. 65, p. 305–312.

McKeague, Brydon and Miles, (1971), "Differentiation of forms of extractable iron and aluminum in soils" in Soil Science Society of America Proceedings, vol. 35, p. 33–38.

McKeague, J.A., Editor, (1976), Manual on Soil Sampling and Methods of Analysis. Prepared by Subcommittee (of Canada Soil Survey Committee) on Methods of Analysis, Soil Research Institute, p. 94–102.

Meuller-Dombois, P., Ellenberg, H., (1974), Aims and Methods of Vegetation Ecology, Wiley and Sons, New York, p. 45–48.

Muller, J.E., (1967), "Kluane Lake map area, Yukon Territory", in Geological Survey of Canada, Memoir 340, 137 pages.

Paterson, W., (1981), The Physics of Glaciers, 2nd. Edition, Pergamon Press Ltd. Oxford, p. 42–57.

Viereck, L.A., (1966), "Plant succession and soil development on gravel outwash of Muldrow Glacier, Alaska" in Ecological Monographs, vol. 36, no. 3, p. 181–199.

Webber, B.L., (1974), The Climate of Kluane National Park, Yukon Territory, Project report no. 6, Atmospheric Environment Service — Meteorological Branch, Toronto.

Normales climatiques au Canada, 1951–1980. Températures et précipitations. Le Nord — T.Y. et T. N.-O. Publication du programme climatologique canadien, Environnement Canada, Service de l'environnement atmosphérique, 1982, p. 1–17.

Weatherwise, American meteorological Society, vol. 11, no. 5 octobre 1958 à vol. 20, no. 5, octobre 1967, p. 175, 207, 213, 215, 219, 227, 229, 237, 239.

SEDIMENTOLOGY AND STRATIGRAPHY OF COAL-BEARING CRETACEOUS-TERTIARY STRATA ON THE SOUTHEAST COAST OF BAFFIN ISLAND

A.B. Langille and E.T. Burden

Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X5

Level: A.B. Langille, Master's

Abstract

Hydrocarbon seeps were discovered off the coast of Baffin Island in Scott Inlet and in Buchan Gulf in 1976 and 1979 respectively. These discoveries renewed interest in the Mesozoic and Cenozoic Sedimentary rocks exposed along the southeast coast of Baffin Island and the possibility that hydrocarbon-bearing rocks may exist below Baffin Bay and Davis Strait. During the summer of 1985, geologic field work was conducted on the sedimentary outliers of Cretaceous-Tertiary age which exist between Cape Dyer and Quqaluit Island on the southeast coast of Baffin Island. This sedimentological and palynological investigation is an attempt to refine part of the geologic history of the Canadian North Atlantic. The sedimentary rocks; sandstones, shales, and minor coals, were deposited in a fluvial environment between 106 (Albian) and 60 (Paleocene) million years ago. The sediments contain the type of organic matter (Lipid) which would source oil if subjected to the necessary parameters of time and temperature. Therefore, it is not unrealistic to state that offshore sediments may host hydrocarbons.

Key words: Hydrocarbons, Baffin Island, sedimentology, Cretaceous, Tertiary, palynology, fluvial.

Résumé

Des suintements d'hydrocarbures avaient été découverts au large de l'île de Baffin, en 1976 dans le goulet de Scott et en 1979 dans le golfe de Buchan. Ces découvertes ont ravivé l'intérêt pour les roches sédimentaires du Mésozoïque et du Cénozoïque exposées le long du littoral est de l'île de Baffin, et la présence possible de roches à hydrocarbures sous la baie de Baffin et le détroit de Davis.

Les auteurs ont effectué des relevés géologiques au cours de l'été 1985 sur les massifs sédimentaires détachés d'âge crétacé/tertiaire en place entre le cap Dyer et l'île Quqaluit, au delà du littoral sud-est de l'île de Baffin. Ce relevé sédimentologique et palynologique visait à préciser l'histoire géologique du littoral canadien de l'Atlantique nord.

Les roches sédimentaires: grès, schistes argileux et minces couches de charbon ont été déposées dans un milieu fluviatile entre −106° Ma (Albien) et −60 Ma (Paléocène). Ces sédiments contiennent les substances organiques (lipides) qui peuvent donner du pétrole si les paramètres de durée et de température sont adéquats. C'est pourquoi on peut présumer que ces sédiments marins contiennent des hydrocarbures.

Mots-clés: Hydrocarbures, île de Baffin, sédimentologie, Crétacé, Tertiaire, palynologie, fluviatile.

Introduction

The discovery of hydrocarbon slicks off the coast of Baffin Island in 1976 and again in 1979, by scientists aboard government research vessels, renewed interest in the sedimentary outliers exposed along the southeast coast of Baffin Island (Loncarevic and Falconer, 1977; Maclean and Falconer, 1979).

The first known published report to briefly discuss the presence of sediments in the Padloping Island area is Sutherland (1853). He reported the occurrence of coal at Cape Durban (Durban Island). After the initial report by Sutherland, attention turned to the volcanics which overlie the sediments. Many comparative studies, of Baffin Island and west Greenland, were conducted through the late 1960's and early 1970's: Wilson and Clarke (1965) and Clarke (1967, 1968, and 1970). With renewed interest in

Figure 1. Map of Baffin Bay region showing geographic localities referred to in the text, and the location of oceanic crust.

hydrocarbon self-sufficiency in the 1970's, attention once again turned to the sediment stratigraphy. This study will examine the sedimentology, palynology, and coal petrology of the Cretaceous-Tertiary sediments on the southeast coast of Baffin Island to contribute to a more accurate understanding of the geology of one of Canada's northern, potentially economic, regions.

Regional geological setting

The tectonic history of the formation of the Labrador Sea and Baffin Bay is a complex, and to date, contested issue. The present geological setting is explained by invoking one of two seafloor spreading models. The first states that Baffin Bay formed in the Paleogene as seafloor spreading along the western arm of the Mid-Atlantic Ridge separated Labrador and Baffin Island from Greenland (Clarke and Upton, 1971; Keen *et al.*, 1972, 1974; Srivastava, 1978; and Jackson *et al.*, 1979). In proposing this model Clarke and Upton (1971) noted that there are many "supposed" geologic similarities between the sediments and volcanics in the study area and outliers of sediments and volcanic basalts on the western coast of Greenland at Disko Island (Fig. 1). In addition, Clarke and Upton (1971) reported that the floral assemblage in the study area strongly resembles that of the Upper Atanikerdluk series of west Greenland. Likewise, information in a paper by Henderson *et al.* (1981) suggests that both areas possess strata of similar continental origin.

The second model states that Baffin Island and Greenland did not drift apart to form Baffin Bay but that continental crust is continuous from Baffin Island across Baffin Bay and on to Greenland. In this scenario Baffin Bay formed by the floundering of continental crust by extensional forces; little new oceanic crust was produced (Grant, 1975, 1980; Umpelby, 1979; Kerr, 1980). There is evidence of a small belt of oceanic crust near the centre of Baffin Bay off the Cape Hooper to Bylot Island coast (Fig. 1). Evidence of oceanic crust has not been recognized in Davis Strait east of Cape Dyer (pers. comm. J. Knill, and O. Friedenreich).

Study area

The field area for the outcrop study lies off the southeast coast of Baffin Island, on Padloping, Durban, and Quqaluit islands (Fig. 2).

Precambrian basement on these islands consists of migmatized, amphibolite to granulite facies gneisses composed of quartz, feldspar, and biotite; apatite, muscovite, garnet, epidote, zircon, and magnetite occur in minor amounts (Clarke and Upton, 1971). The gneisses are cut by pegmatite dykes and on Durban Island by a muscovite-tourmaline granite. A regolith, usually five to ten metres thick, is commonly observed on basement rock which is covered by younger beds. The regolith consists of weathered boulders and pebbles of bedrock weakly bound together in a yellow-orange clay matrix.

Unconformably overlying the gneiss and regolith are poorly lithified sandstones and shales with minor coal locally. These sandstones are composed of locally derived quartz, feldspars, and biotite (Sears, 1986).

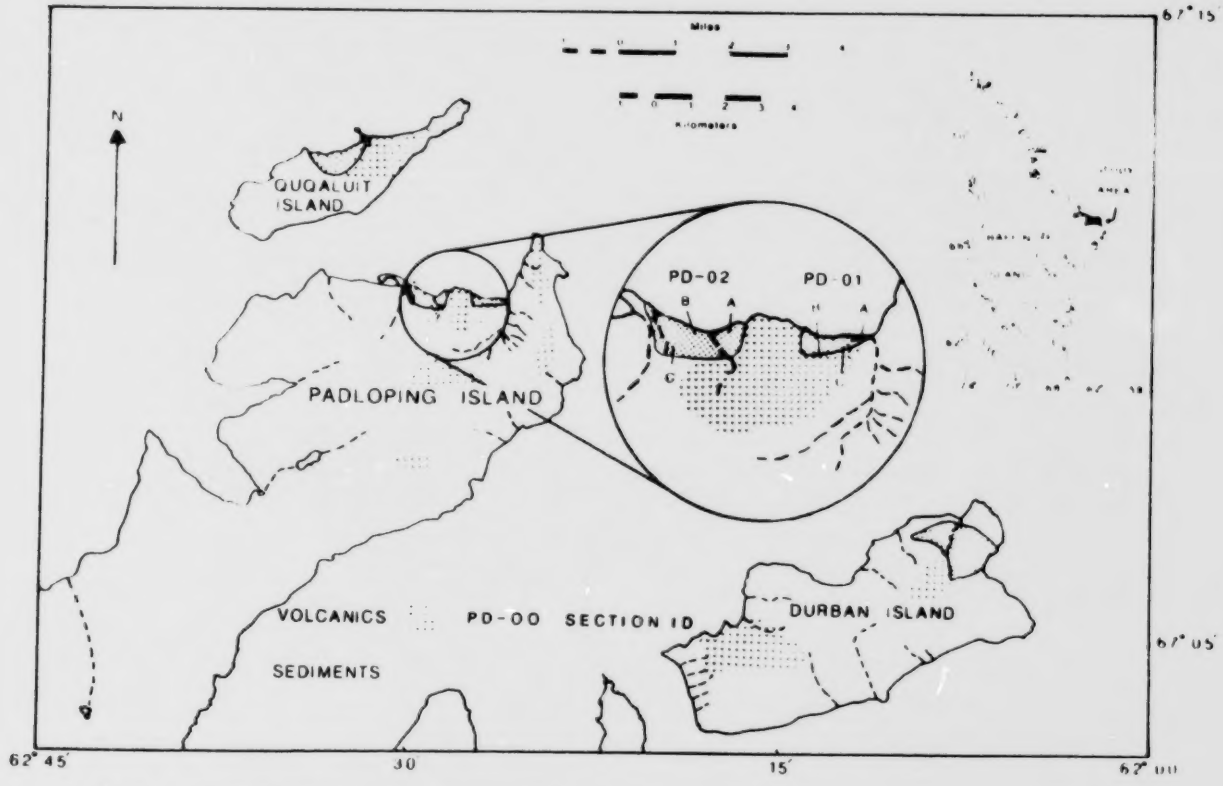


Figure 2. Map of field area showing distribution of Cretaceous-Tertiary sediments and overlying volcanic rocks.

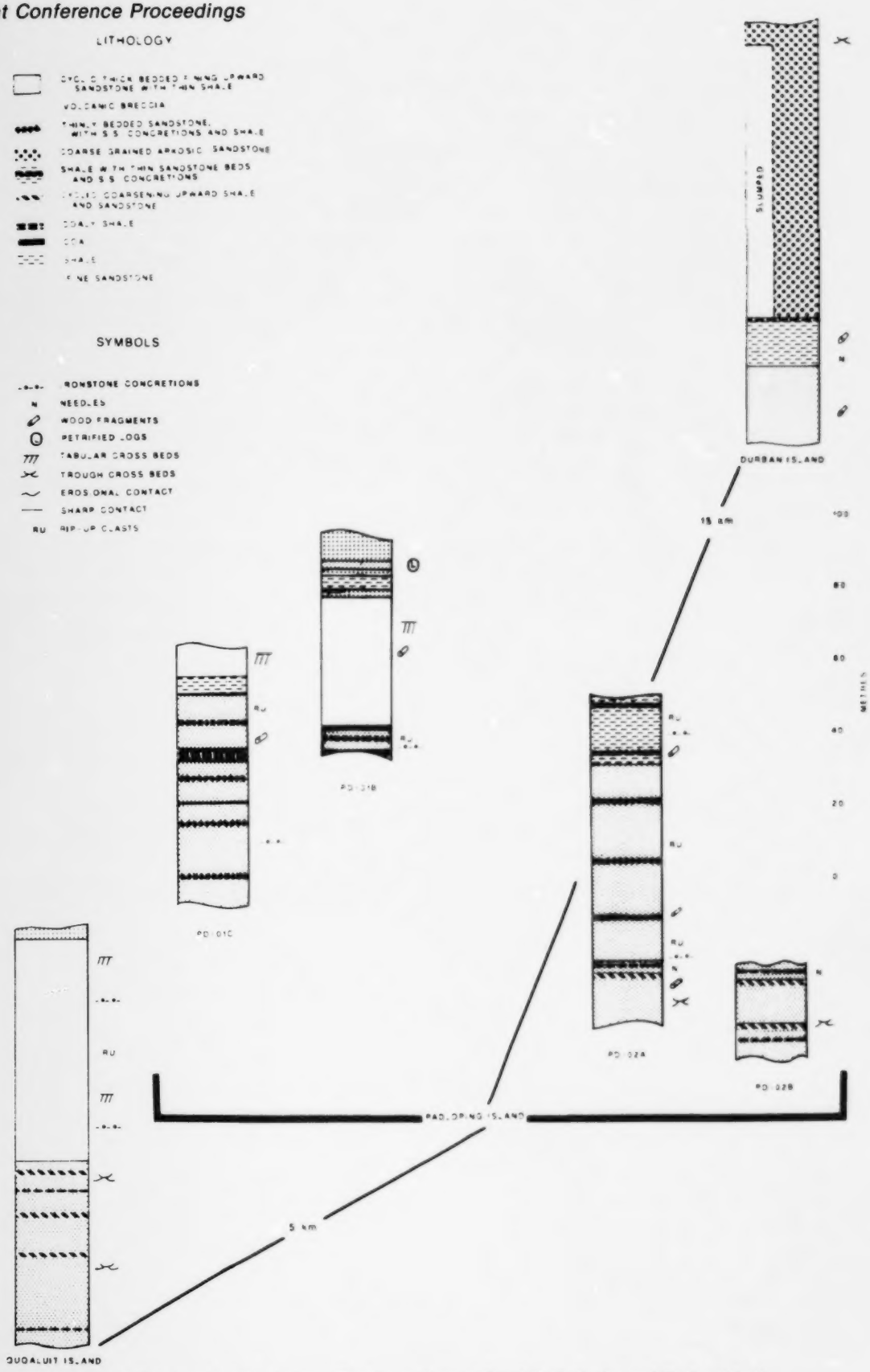


Figure 3: Stratigraphy of Cretaceous-Tertiary outliers on Quqaluit, Padloping and Durban islands.

The sedimentary strata on the three islands occur in small fault-bounded basins on the migmatized Precambrian gneissic basement. Sections were disrupted by post-depositional faulting, soft-sediment deformation and cryogenic activity. The soft, unconsolidated sands with distorted sedimentary structures and obscured lateral relationships made palinspastic reconstruction and interpretation difficult (Figure 3) (Langille *et al.*, 1986).

Conformably overlying the sediments are volcanic breccias and sheet flows of picritic basalt (Clarke and Upton, 1971). The exact age of these basalts is questionable; a K-Ar date, obtained in the late 1970's, is considered unreliable due to the composition of the basalt. Research into resolving this problem is continuing. A complete discussion on the geology of the basalts can be found in Clarke and Upton (1971).

Field work

Samples for sedimentological, palynological, and coal petrological analyses were collected systematically through the sections on all three islands and where sedimentology became complex more attention was given and a closer sample interval employed.

Samples of tree bark, woody material, petrified wood, and coniferous needles were collected from Padloping, Quqaluit, and Durban islands. These samples are presently being analysed for taxonomic affinities and subsequent age determination.

Stratigraphy

Padloping Island

The Padloping Island section (Fig. 3) is a composite of 4 separate outcrops on the north coast of the island (Fig. 2). The exposed sequence is approximately 150 m thick. The lower contact, presumably an unconformity on Precambrian gneiss, was not observed; it is estimated to lie approximately ten metres below the base of outcrop PD-02B (Sears, 1986). The lowermost 30 m (approx.) of the composite section consist of shales and sandstones in coarsening-upward cycles. The upper three to five metres of each coarsening-upward cycle is extensively trough cross-bedded and pebbly (Fig. 4). Above this lie 75 metres of poorly consolidated, medium grained, quartz-rich sands with zones of calcareous concretions, organic rich shales, thin, laterally discontinuous coals, and one thick homogeneous shale. The section is topped by 45 metres of thick-bedded sandstones with thin shales in fining-upward cycles. The upper contact is conformable with the overlying volcanic strata.

Above the contact, thin basaltic volcanic breccia are commonly interbedded with fine sandstones. Logs and other plant debris are common in the sediments at the contact with the basalt.

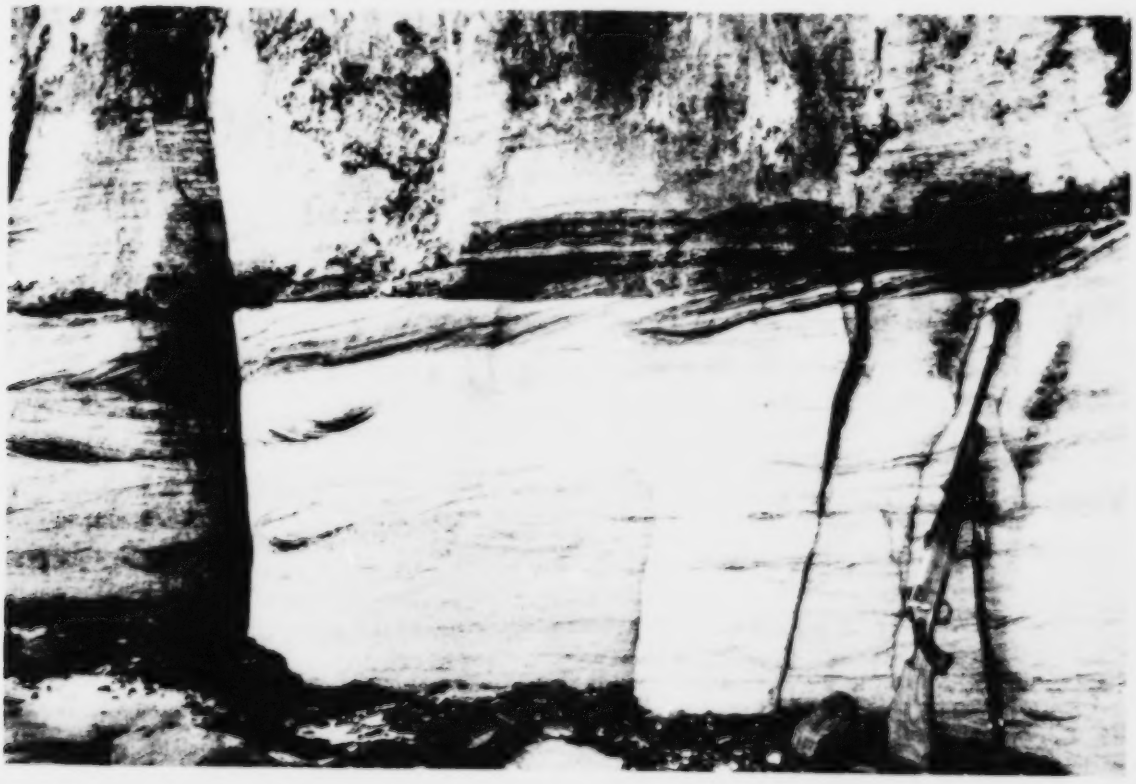


Figure 4. Trough cross-bedded sandstones at the top of a coarsening upward cycle (from Langille *et al.*, 1986).

Figure 5. (A) Channel cut and fill on Quqaluit Island.

(B) Epsilon cross-bedding above channel cut and fill on Quqaluit Island.

Quqaluit Island

The sedimentary strata lie unconformably on a five to ten metre thick regolith of Precambrian gneiss. The lower 50 metres of section consist of shales and sandstones in coarsening-upward cycles. The upper 60 metres are cyclic, thick bedded, fining upward sandstones with thin shales in fining-upward cycles. Channel cut-and-fill deposits with epsilon cross-beds (Fig. 5 A and B), ironstone concretions, rip-up clasts, and thin shale beds are common in the upper 60 metres. The top of the section at 110 metres consists of interbedded sandstone and volcanic breccia beds.

Durban Island

The strata lie unconformably on 5 metres of regolith of Precambrian gneiss. From its base the section consists of 20 metres of sandstone overlain conformably by 25–30 metres of "papery" shale. Above the shale to the highest point observed there lie approximately 60 metres of slumped, flaggy, well indurated, arkosic sandstone with thin shale beds. The top five metres of this unit are in place and consist of indurated coarse grained, trough cross-bedded arkosic sandstone.

Organic maceral identification and vitrinite reflectance

Detailed organic maceral identification has been conducted on four coal samples from Padloping Island. Average percent values of total vitrinite, total inertinite, and total liptinite are summarized in Table 1.

Vitrinite reflectance measurements collected for coal in the Padloping Island section range from 0.48% to 0.55%.

Paleobotany

Floral remains described by McMillan (1910) and Bell (in Clarke and Upton, 1971) are considered to be Paleocene in age. These authors noted a marked similarity to floral remains from nonmarine strata of the Upper Atanikerdluk series of west Greenland. Fossil plants, if accurately dated will be a great asset to this study. However, there exists some controversy since Choi *et al.* (1984) have evidence to suggest Tertiary plants evolved in the Arctic during the Cretaceous.

From our study, samples of coniferous needles thought to be *Elatides* (?), an Aptian-Albian conifer, are in strata containing tree bark of Taxodiaceae affinity (upper

MACERAL IDENTIFICATION

SAMPLE NO.	01C-19A	01A-00	01C-11	01C-15
PERCENTAGE				
Mineral	5	6	9	9
Other	0	0	0	0
TOTAL VITRINITE	33	30	34	39
TOTAL INERTINITE	42	33	35	38
Semifusinite	3	2	3	2
Fusinite	9	6	6	6
Micrinite	30	25	26	30
SOLID HYDROCARBON	0	0	0	0
TOTAL LIPTINITE	20	31	22	14
Resinite	2	10	7	1
Sporinite	2	1	2	2
Cutinite	9	0	1	6
Alginite	6	19	10	4
Liptodetrinite	1	1	2	1
KEROGEN	0	0	0	0

TABLE 1
Maceral Identification on 4 coal samples from Padloping Island: Percentage listings

Cretaceous-Tertiary). Overall, the woody material which has been preserved shows generalized characteristics of "*Sequoioxylon*" (upper Cretaceous-Tertiary) (Basinger, pers. comm.). At this stage an accurate age assignment, on the basis of the fossil wood, cannot be made.

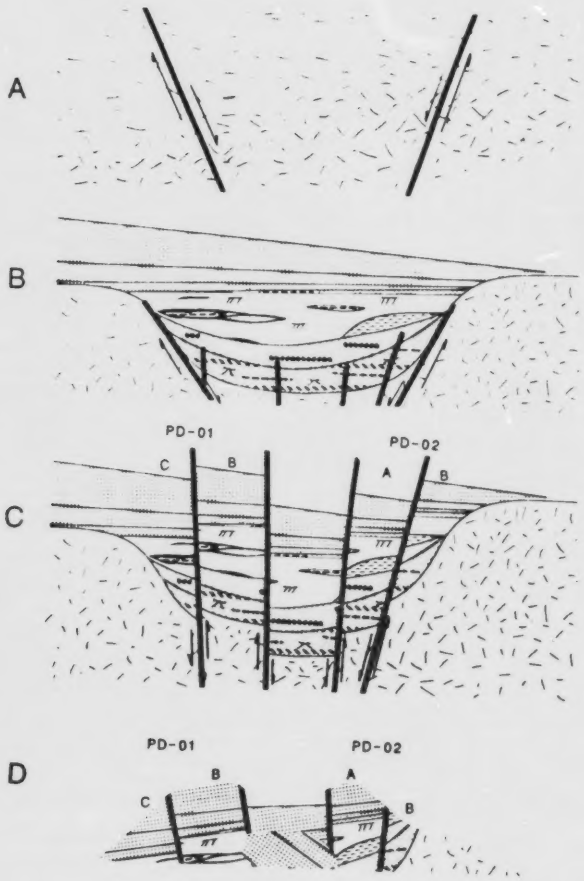


Figure 6. Vertical sections representing development of the Padloping Island sedimentary basin (from Sears, 1986).
A: Basement is faulted by extension.
B: Sediments and volcanics are emplaced as minor faulting continues.
C: Late stage faulting disrupts the area causing major slumping.
D: Present area of exposure.

Palynology

Sixteen samples have been examined for palynomorphs. All slides contain abundant woody material with cuticle and resin. Palynomorph assemblages, as stated by Langille *et al.* (1986) are dominated by *Alisporites bilateralis* Rouse, 1959, *Cedripites canadensis* Pocock, 1962, *Parvisaccites radiatus* Couper, 1958, *Podocarpidites multesimus* (Bolkhovitina) Pocock, 1962 and *P. canadensis* Pocock, 1962. Biostratigraphically useful species include *Appendicisporites matesovai* Bolkovitina, 1968, *Cicatricosisporites auritus* Singh, 1971, *Clavifera* sp. cf. *C. rudis* Bolkhovitina, 1968, *Concavissimisporites parkinii* Pocock, 1962, *Densoisporites microrugulatus* Brenner, 1963, *Foveogleicheniidites confossus* (Hedlund) Burger, 1976, *Foveosporites canalis* Balme, 1957, *Impardecispora marylandensis* (Brenner) Venkatachala, Kar and Raza, 1968, *Retitricolpites promiscuus* Laing, 1975 and *Saxetia scurrandus* (Norris) Srivastava, 1975, *Trilobosporites hannonicus* (Delcourt and Sprumont) Pontonie, 1956. This assemblage indicates a non-marine deposit of Albian or Cenomanian age.

Discussion

Structure

The strata have been affected by post-depositional extensional tectonic processes. The strata have been faulted, rotated, slumped and uplifted to produce the present day exposure. Also, soft sediment deformation and cryogenic activity has distorted many sedimentary structures and destroyed the lateral continuity of beds. The possible chain of events leading to the development of the sedimentary basin on Padloping Island is illustrated in Figure 6 (Sears, 1986).

It has been suggested that the section on Durban Island is 250 metres thick (Clarke and Upton, 1971). However, work by Langille *et al.* (1986) and Sears (1986) indicates an alternate explanation whereby three faulted and rotated blocks repeat the section. The authors propose a section 110 metres thick (Fig. 3).

Depositional history

The overall depositional environment was fluviatile. Sedimentary structures and gross sediment type and style suggest both meandering and braided stream deposition.

Small scale (< 10 cm thick) trough cross-bedded sediments capping coarsening-upward sequences are present near the base of the Padloping Island section. These sedimentary structures may have been deposited by the migration of small dunes in a braided stream bed.

A fining-upward sequence which shows epsilon cross bedding (lateral accretion surfaces) is commonly cited as relatively reliable evidence of meandering stream deposits (Cant, 1982). Channel cut and fill deposits (Fig. 5A) along with epsilon cross-bedding (Fig. 5B) are common sedimentary structures in the upper 60 metres of the section on Quqaluit Island. Therefore, the presence of these structures suggests that point bar deposits are represented in a meandering stream complex.

Coals and organic rich shales are common in fluvial sedimentary environments (Horne *et al.*, 1978). Laterally discontinuous, thinly bedded coals and organic rich shales are present in the Padloping Island section and probably represent deposition in backswamp regions located between channels.

The arkosic coarse sands on Durban Island are unique, both in type and thickness. These sands may represent an alluvial fan deposit. The fine "papery" shales underlying the arkosic sands on Durban Island are indicative of quiet, probably lacustrine deposition prior to the onset of alluvial fan deposition.

The presence of logs, log and plant debris, and coniferous needles and lack of marine fauna or flora support a

continental environment for the strata on the three islands. The abundance of floral remains near the contact with the overlying volcanics suggests that the volcanism destroyed a Cretaceous-Tertiary forest in the area. This volcanism is represented by the basalts and basaltic breccias conformably overlying the sedimentary sections.

Source rock potential and maturity

Vitrinite forms the humic fraction of coal and has very little liquid hydrocarbon generative potential. A vitrinite-rich source would generate gas at maturity. The inertinite maceral group consists of components of coal which are more or less non-reactive and have very low hydrocarbon generative potential. Liptinite, a hydrogen-rich maceral group, has the highest potential for liquid hydrocarbon generation (Gutjahr, 1983).

According to Gutjahr's (1983) classification of potential source rocks, the Padloping Island coals place as Type 3b *landplant-containing* source rocks. These source rocks are typical humic (vitritic) coals and carbonaceous shales (Gutjahr, 1983). The major constituent is vitrinite, although significant percentages of lipid and inertinite macerals are present (Table 1). Therefore, it is suspected that these potential source rocks may produce both oil and gas, given a proper maturation history.

Vitrinite reflectance values for coals from Padloping Island range from 0.48% to 0.55%. This suggests that these sediments, in terms of hydrocarbon generation, are immature, and that the coal is sub-bituminous.

Conclusions

Investigation to date indicates that the sediments on Padloping, Quqaluit, and Durban islands represent deposition in a fluvial environment. Coals and organic rich shales likely represent deposition between main stream channels in backswamp regions. Voluminous plant debris and well preserved logs in the sediments near the contact with the basalts probably represent the results of destruction of a Cretaceous-Tertiary forest by volcanic activity in the immediate area. Stratigraphic position and deposition style suggests that these strata probably represent a new formation of the Eureka Sound Group.

Palynology indicates that the outliers are probably older than Paleocene. Paleobotany is inconclusive, although further work may prove more fruitful.

Vitrinite reflectance and maceral identification performed on samples of coal from Padloping Island indicate that the sediments are immature, but may be oil and gas producing if buried to sufficient depth offshore.

Acknowledgments

Accommodations provided by both Parks Canada (Broughton Island) and the Department of Indian Affairs and Northern Development (Frobisher Bay), while traveling to and from the field were appreciated. Guides, Lymeckee Kakee and Julie Koonalusie, were invaluable and without their enthusiastic support the project could not have been as successful. Discussions with E. Deutsch, B. Sears, L. Newman, Shell Canada (Frontier Division) geologists, Texaco Canada geologists, and J. MacMillian were very helpful and informative. Vitrinite reflectance and organic identification assistance from Mike Radchuck of Shell Canada was greatly appreciated. J. Basinger's continuing assistance with paleobotany is invaluable and for this we are extremely grateful. Financial and logistical support was provided by the Geological Survey of Canada (E.B.), Natural Sciences and Engineering Research Council (E.B.) and Polar Continental Shelf Project (E.B.), a Texaco Research Grant (A.L.), and Department of Indian Affairs and Northern Development — Northern Scientific Training Program.

References

Burden, E.T., and Holloway, D.C. (1985). Palynology and age of the Scott Inlet inliers of Baffin Island (Northwest Territories), Canadian Journal of Earth Sciences 22:1542–1545.

Cant, D.J., 1982. Fluvial facies models and their application. In: Scholle, P.A., and Spearing, D., eds. Sandstone Depositional Environments. Tulsa: American Association of Petroleum Geologists. 115–137.

Choi, D.K., Traverse, A., and Hickey, L.J. 1984. Eureka Sound Formation (Late Cretaceous-Paleogene) Palynofloras from the Canadian Arctic, in relation to Angiosperm Migration. Sixth International Palynological Conference, Calgary, pp. 21.

Clarke, D.B. 1967. Tertiary basalts from Baffin Island and west Greenland. Proceedings of the Geological Society of London 1673:50–51.

Clarke, D.B. 1968. The basalts of Svartenhuk Peninsula. Progress report. Greenland Geological Survey 15:15–17.

Clarke, D.B. 1970. Tertiary basalts of Baffin Bay: possible primary magma from the mantle. Contributions to Mineralogy and Petrology 25:203–224.

Clarke, D.B., and Upton, B.G. 1971. Tertiary basalts of Baffin Island: Field relations and tectonic setting. Canadian Journal of Earth Sciences 8:248–258.

Deutsch, E., and Patzold, R.R. 1984. A discordant early Tertiary pole position from the Cape Dyer lavas, Canadian Arctic. E.O.S. 65:200.

Grant, A.C. 1975. Geophysical results from the continental margin off southern Baffin Island. In: Yorath, C.J., Parker, E.R., and Glass, D.J. eds. Canada's continental margins and offshore Petroleum Exploration. Calgary: Canadian Society of Petroleum Geologists: Memoir 4:411–413.

Grant, A.C. 1980. Problems with plate tectonics: Labrador Sea. Canadian Society of Petroleum Geologists: Bulletin 28:252–278.

Gutjahr, C.C.M. 1983. Introduction to incident-light microscopy of oil and gas source rocks. In: van den Berg, M.W. and Felis, R. eds. Special issue in the honour of J.D. de Jong — Geology en Mijnbouw 62:417–425.

Henderson, G., Schiener, E.J., Risum, J.B., Croxton, C.A., and Anderson, B.B. 1981. The West Greenland Basin. In: Kerr, J.W., Fergusson, A.J., eds. Geology of the North Atlantic Borderlands. Calgary: Canadian Society of Petroleum Geologists: Memoir 7:399–428.

Horne, J.C., Ferm, J.C., Caruccio, F.T., and Baganz, B.P., 1978. Depositional models in coal exploration and mine planning in the Appalachian region. American Association of Petroleum Geologists: Bulletin 62:2379–2411.

Jackson, H.R., Keen, C.E., Falconer, R.K., and Appleton, K.P. 1979. New geophysical evidence for sea floor spreading in central Baffin Bay. Canadian Journal of Earth Sciences 11:2122–2135.

Keen, M.J. and Clarke, D.B. 1974. Tertiary basalts of Baffin Bay: Geochemical evidence for a fossil hotspot. In: Kristjansson, L. and Reidal, D. eds. Geodynamics of Iceland and the North Atlantic area. Dordrecht-Holland: 127–137.

Keen, M.J., Johnson, J. and, Park, I. 1972. Geophysical and geological studies in eastern and northern Baffin Bay and Lancaster Sound. Canadian Journal of Earth Sciences 9:689–708.

Kerr, J.Wm. 1980. Evolution of the Canadian Arctic Islands — A transition between the Atlantic and Arctic oceans. In: Naire, A.E.M., Stehli, F.G., and Churkin, M.Jr. eds. The oceans basins and margins. New York: Plenum Press. 5: The Arctic Ocean.

Langille, A.B., Burden, E.T., Sears, W.B., and Holloway, D.C. 1986. Geological investigation of Cretaceous? Strata beneath Cape Dyer Basalts (Paleocene), Baffin Island, District of Franklin. Geological Survey of Canada, Paper 86-1A:483–487.

Loncarevic, B.D. and Falconer, R.K. 1977. An oil slick ocurrence off Baffin Island. Geological Survey of Canada: Paper 77-1A:523–524.

MacLean, B. 1978: Marine geological-geophysical investigations in 1977 of the Scott Inlet and Cape Dyer-Frobisher Bay areas of the Baffin Island continental shelf: Geological Survey of Canada: Paper 78-1B:13–20.

MacLean, B., and Falconer, R.K. 1979. Geological/Geophysical studies in Baffin Bay and Scott Inlet-Buchan Gulf and Cape Dyer-Cumberland Sound areas of the Baffin Island Shelf: Geological Survey of Canada: Paper 79-1B:231–244.

MacLean, B., and Williams, G.L. 1980: Upper Cretaceous rocks in Baffin Bay: Geological Association of Canada, Program with Abstracts: 5:69.

MacLean, B., and Williams, G.L. 1983: Geological Investigations of Baffin Island Shelf in 1982. Geological Survey of Canada, Paper 83-1B:309-315.

MacMillan, J.G. 1910. Report of the Dominion of Canada Government Expedition to the Arctic Islands and Hudson Strait on Board the D.G.S. "Arctic". In: Bernier, J.E., Government Printing Bureau, Ottawa.

McMillan, N.J. 1973. Shelves of the Labrador Sea and Baffin Bay, Canada. In: McCrasson, R.G. ed. Future Petroleum provinces of Canada. Calgary: Canadian Society of Petroleum Geologists: Memoir 1:473-517.

McWhae, J.R. 1981. Structure and spreading history of the Northwest Atlantic region from the Scotian Shelf to Baffin Bay. In: Kerr, J.W. and Ferguson, A.J. eds. Geology of the North Atlantic Borderlands. Calgary: Canadian Society of Petroleum Geologists: Memoir 7:299-332.

Miall, A.D., Balkwill, H.R., and Hopkins, W.S. 1980. Cretaceous and Tertiary sediments of Eclipse trough, Bylot Island area, Arctic Canada, and their regional setting. Geological Survey of Canada, Paper 79-23:20.

Miall, A.D. 1986 The Eureka Sound Group (Upper Cretaceous-Oligocene), Canadian Arctic Islands. Canadian Society of Petroleum Geologists: Bulletin 34:2:240-270.

Sears, W.B. 1986: An investigation of sedimentary outliers on Quqaluit, Padloping and Durban islands, Baffin Island. Unpublished B.Sc. thesis, Memorial University of Newfoundland, 77 p.

Srivastava, S.P. 1978: Evolution of the Labrador Sea and its bearing on the early evolution of the North Atlantic: Geophysical Journal, Royal Astronomical Society 52:313-357.

Sutherland, P.C. 1853. On the geological and glacial phenomena on the coast of Davis Strait and Baffin Bay. Quarterly Journal of the Geological Society of London 9:296-312.

Umpelby, D.C. 1979. Geology of the Labrador Shelf. Geological Survey of Canada, Paper 79-13:39.

Wilson, J.T., and Clarke, D.B. 1965. Geological expedition to Capes Dyer and Searle, Baffin Island, Canada. Nature 205:349-350.

MODIFICATION OF THE GREAT WHALE RIVER, QUÉBEC, PLUME DURING ICE BREAKUP*

S. Lepage and R.G Ingram

Institute of Oceanography, McGill University, Montréal, Québec H3A 2B2

*(*Contribution to the program of Giroq, Groupe interuniversitaire de recherches océanographiques du Québec).*

Level: S. Lepage, Ph.D.

Abstract

Studies of coastal circulation dynamics were conducted in proximity to the Great Whale River, Québec (Hudson Bay), in the winter-spring periods of 1985 and 1986. Recently, the importance of an ice cover in modifying the mixing of fresh water with the ambient salt water has been shown in eastern James and Hudson Bay. The purpose of the present study was to describe plume conditions of the Great Whale River during ice breakup. Observations showed that for the reduced turbulence levels under a winter ice cover, fresh water dilution occurs very slowly, producing large areas of brackish water in the coastal zone. Fresh water accumulates until the late May-early June breakup. As the ice retreats, direct wind forcing acts over the surface layer and increases mixing with the underlying water. The overall effect is a shrinking of the river plume area, although the early summer discharge is five times larger than that prior to breakup in the river.

Key words: Hudson Bay, physical oceanography, plume, Great Whale River, Québec, ice breakup.

Résumé

Au cours des années 1985 et 1986, une recherche océanographique ayant pour objet d'étude la dynamique de circulation côtiere, a été menée près de l'embouchure de la Grande Rivière de la Baleine, baie d'Hudson. Récemment, l'importance du couvert de glace comme agent modificateur du mélange de l'eau douce avec l'eau salée ambiante fut mise en évidence dans le secteur est des baies James et d'Hudson. La présente étude a pour but la description du panache de la Grande Rivière de la Baleine durant la débâcle des glaces. Les observations montrent que sous le couvert de glace hivernal, la faible turbulence résulte en une dilution très lente de l'eau douce, ce qui produit une zone étendue d'eau saumâtre dans la région côtière. L'eau douce s'accumule jusqu'à la débâcle qui a lieu fin mai-début juin. À mesure que la glace se résorbe, l'effet éolien se fait directement sentir sur la couche d'eau superficielle, produisant ainsi un mélange accru avec la couche sous-jacente. Le résultat global est un rétrécissement du panache de la rivière alors que le débit estival est cinq fois supérieur que celui d'avant débâcle.

Mots-clés: Baie d'Hudson, océanographie physique, panache, Grande Rivière de la Baleine, Québec, débâcle.

Introduction

The surface of Hudson Bay is almost 100% covered by ice from January to April each year (Danielson, 1971). Although it is the largest body of water in the world that is virtually covered by sea ice in winter and entirely ice-free for a few months in late summer-early fall, very little was known about oceanographic processes in the Bay until recently. Since 1976, under the impetus of the development of the hydroelectric potential of Northern Québec, a number of oceanographic studies have focussed on the eastern shore of James and Hudson Bay. Areas studies include: Rupert Bay, Eastmain, La Grande and Great Whale River estuaries. Other projects have dealt with the coastal circulation and salinity structure.

Because of the remote location, the long period of sea ice, breakup and the severe fall-winter meteorology, year-round samplings have not been possible to date. Existing data have been mainly collected during the short open water period (July-September) or in late winter, when one can rely on a stable ice cover in most years (March-May). Oceanographic information during the ice formation and breakup periods is virtually non existent.

In this paper, we examine the gradual changes that occurred in the salinity structure and circulation in the Great Whale River coastal area on the basis of data collected during the ice breakup periods of 1985 and 1986.

Variability of oceanographic features in Hudson Bay

Studying modifications of the Great Whale River plume during breakup requires a basic knowledge of the Hudson Bay seasonal dynamics. Although it is an immense body of water (1.6×10^{14} m^3), Hudson Bay is considered as a large estuarine-type system with important fluctuations of its salinity, temperature and currents structure throughout a year (Prinsenberg, 1982; Pett and Roff, 1982). The freshwater input to Hudson Bay, which comes mainly from James Bay, varies from about 10^4 m^3 s^{-1} in March to over 4×10^4 m^3 s^{-1} in June. If one includes precipitation and evaporation effects, the system has a net freshwater loss of 3×10^3 m^3 s^{-1} in April and net maximum gain of 4.3×10^4 m^3 s^{-1} in June. Over a complete year, this represents an addition of over 5×10^{11} m^3 of water which leaves the Bay as surface outflow (Prinsenberg, 1980).

In order to complete the annual cycle of surface layer characteristics in central Hudson Bay, Prinsenberg (1983) developed a one-dimensional mixed-layer model. The results obtained predict a large variation in depth of the seasonal pycnocline, with a minimum depth of less than 5 m in late May and a maximum of 62 m in early May when the sea surface salinity (SSS) reaches 32°/oo. The minimum SSS of 29 °/oo occurs in July. The sea surface temperature (SST) is inversely related to the SSS with a minimum SST of −2°C in late May and a maximum SST of 9°C in August. These large fluctuations are explained by the net balance between the surface fluxes. In summer, high runoff, solar heating and low wind speeds cause a shallow pycnocline depth. Maximum SST and minimum SSS are reached before the pycnocline begins to deepen in late summer when wind stress increases and heat input, as well as runoff, diminish. Deepening in pycnocline depth continues in fall and early winter due to sea surface cooling and salt rejection from the ice formation. During this period, SST values remain constant while SSS rises. In late winter, when ice growth stops and freshwater discharge increases, the pycnocline stabilizes. It then rapidly returns to the minimum value in spring when large runoffs are followed by maximum ice melt and heat flux input. The seasonal pattern described above is that most likely to occur in south-east Hudson Bay. However, local observations show that ambient SST and SSS values are somewhat different (Ingram, 1981; Larouche, 1984a; 1984b).

In terms of general circulation in Hudson Bay, the first evidence of cyclonic surface motion was described by Hachey (1935). This was corroborated by the work of Ingram (1981) and Prinsenberg (1982). On the basis of dissolved oxygen data, Pett and Roff (1982) concluded that Hudson Bay deep water motion was also cyclonic, with a turnover rate of between 4 and 14 years.

Sea ice presence modifies both circulation and water mass structure. Working on the variability of the tide in the Canadian Arctic, Godin and Barber (1980) reported that in Amundsen Gulf and Hudson Bay, the presence of an ice cover reduced tidal amplitudes and altered tidal phase. In Eastmain estuary, Ingram (1982) calculated that under-ice tidal maxima occurred 30 to 90 minutes earlier than in open water conditions. Studies of coastal circulation and plume characteristics in the Eastmain (Ingram, 1982; Lepage, 1984), La Grande (Lepage *et al.*, 1985; Ingram and Larouche, 1987b) and Great Whale Rivers (Ingram, 1981; Ingram and Larouche, 1987a) have also shown significant changes related to sea ice cover. This increased knowledge of the physical environment during the ice covered period led to a better understanding of marine productivity in subarctic coastal areas (Legendre *et al.*, 1981; Legendre *et al.*, 1982; Gosselin *et al.*, 1985).

Great Whale River plume

The Great Whale River enters south-eastern Hudson Bay at latitude 55° 16′ North and longitude 77° 48′ West (Fig. 1). Although the lower reaches of the river do not exceed 10 m depth, low water depths at the sill near the river mouth are below 2 m. Within 3 km of the shore the bottom falls to over 60 m. Further offshore in the study area, depths rarely exceed 100 m. The mean annual river runoff is 660 m^3 s^{-1}, ranging from 170 m^3 s^{-1} in March to 1320 m^3 s^{-1} in June (Prinsenberg, 1980). Ice breakup in the river usually occurs during the third week of May and subsequently in the offshore area.

Because of the varying ambient conditions in Hudson Bay, definition of the offshore limit of the Great Whale River plume also differs according to the season. In previous studies, the isohaline of 22 °/oo was taken as the maximum extent of the plume in summer, and 25 °/oo in under-ice conditions (Ingram, 1981; Freeman *et al.*, 1982). In their respective studies, the authors described the plume as being in hydrostatic equilibrium, decoupled from the velocity field underneath.

The summer plume covers a surface area of approximately 100 km^2 and between 1 to 2 m in depth. Typical mean velocities within the plume are 60 cm s^{-1} in amplitude and north-westerly in direction. Near the coast, tidal currents are generally less than 10 cm s^{-1} in amplitude. Coastal longshore currents are approximately 5 cm s^{-1}. Although a large shear in velocity is present between the plume and the underlying water, the surface layer is stable. The source of kinetic energy available for mixing is predominantly from surface waves and meteorological forcing in the 3–5 day frequency band.

The winter coastal dynamics in Great Whale area are greatly modified by the formation of a stable ice cover from late January to late May in most years. Under these conditions, direct wind forcing is virtually eliminated and the primary source of kinetic energy is of tidal origin (Ingram, 1981) and large scale atmospheric forcing through the ice (Ingram and Larouche, 1987a). Tidal amplitude in the study area is relatively weak. Although the winter discharge is five times lower than that in early summer, a much larger plume is developed compared to open water conditions and a sharp pycnocline is found between 3 and 5 m in depth (Ingram and Larouche, 1987a). Stability of the surface layer is evidenced by typical gradient Richardson number one order of magnitude larger than summer values (Ingram, 1981). The mean velocity in the plume is ten times smaller than equivalent

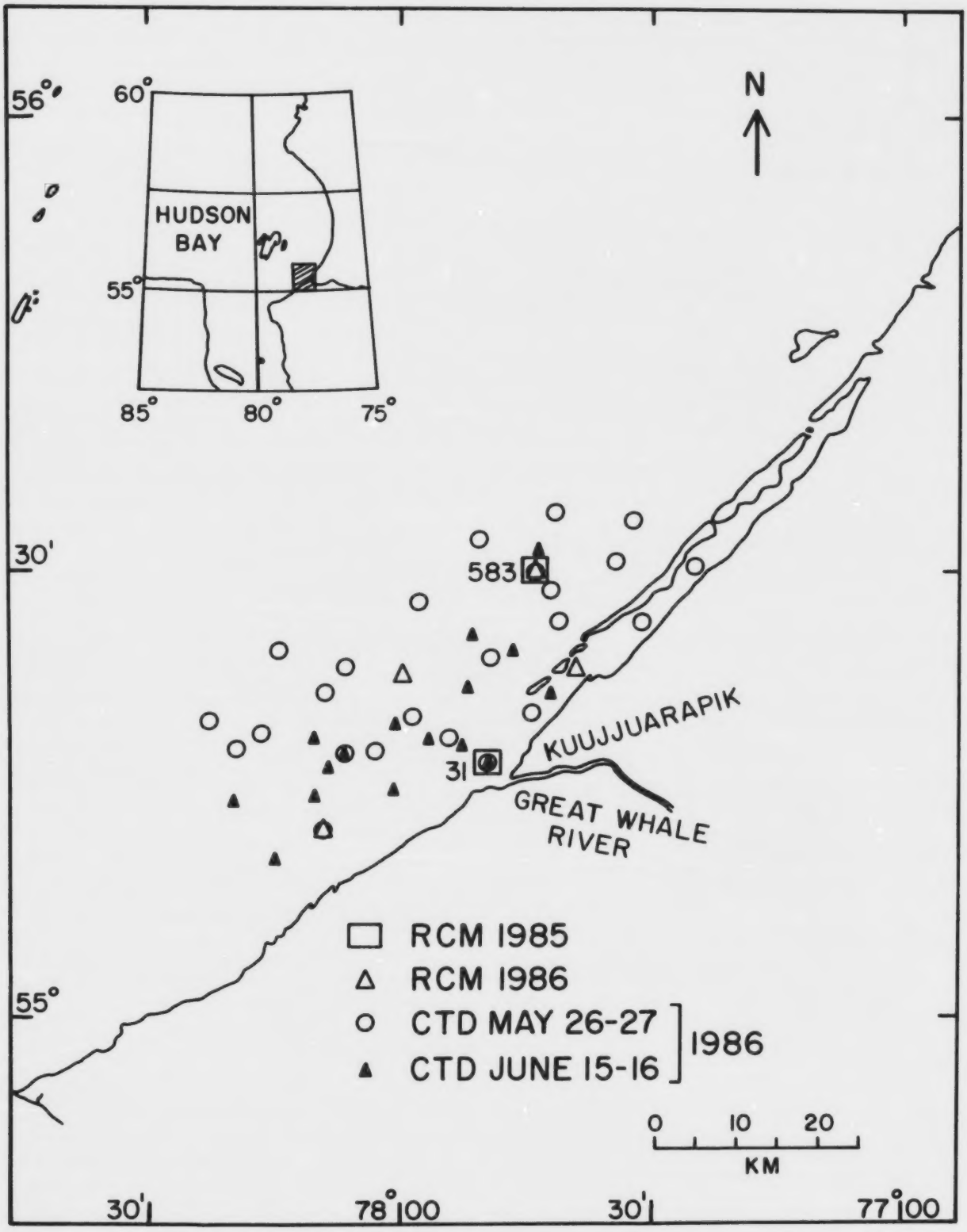


Figure 1. Map of study area including the location of current meter moorings and CTD profiling stations.

summer value due to the low runoff and the presence of a surface frictional boundary layer.

Methods

Two sampling strategies were used to collect the oceanographic data during the breakup period. In 1985, time-series of conductivity (salinity), temperature and current velocity were sampled at two fixed stations using Aanderaa RCM-4 current meters (Fig. 1). Variables were measured every 10 minutes at a depth of 7 m from mid May to early August. In 1986, in addition to fixed moorings, a series of conductivity-temperature-depth (CTD) profiles were executed at a number of grid points scattered over an area of 2000 km^2 to obtain a nearly synoptic view of the plume. On May 26–27, 25 stations were visited and on June 15–16, 17 stations. Between these dates, stations 31 and 583 were surveyed every other day when weather and ice conditions were favorable (Fig. 1). These profiles were done using a Guildline model 8770 CTD probe mounted onboard a Bell 212 helicopter. To compare the breakup characteristics to those prevailing under-ice or those present in open water condition, CTD profiles were also executed in April, July and August. The Guildline instrument was mounted on a sled pulled by a snowmobile for the winter survey. In summer, a Beckman RS-5 salinometer was used onboard an 18 foot surface vessel. Positioning of all oceanographic stations was done with a Del Norte microwave system.

Other current-meter, CTD and meteorological data collected in the area since 1976 were also used to complete the present study. Daily discharge for Great Whale River was obtained from the Ministère de l'environnement du Québec.

Breakup observations

Although historical data show that Hudson Bay freezes over almost completely from January to April, contrasting ice conditions were encountered in the Great Whale area in 1985 and 1986. In 1985, a large section of the Hudson Bay ice cover was unstable and moving. In early May, a large polynya was located to the west of the river mouth (Fig. 2). Open water conditions were present over an area of about 3500 km^2 in Hudson Bay well before breakup in the river. A different situation prevailed in 1986; the ice cover was complete until late May. The entire study area was free of ice only by late July. In the river, breakup occurred on May 17.

The current meter data collected in both 1985 and 1986 were "low-passed" using an $A_{24}A_{24}A_{25}/24*24*25$ filter to remove diurnal and semi-diurnal fluctuations (Godin, 1972). In 1985, variables at both stations 31 and 583 exhibited a similar pattern of fluctuations between early May and late August. At station 583, water temperature rose gradually from -1.5 to approximately 7°C, while salinity dropped from 28 to 24°/oo (Fig. 3). Current velocity was not

Figure 2. Landsat satellite image of south-east Hudson Bay taken on May 5, 1985.

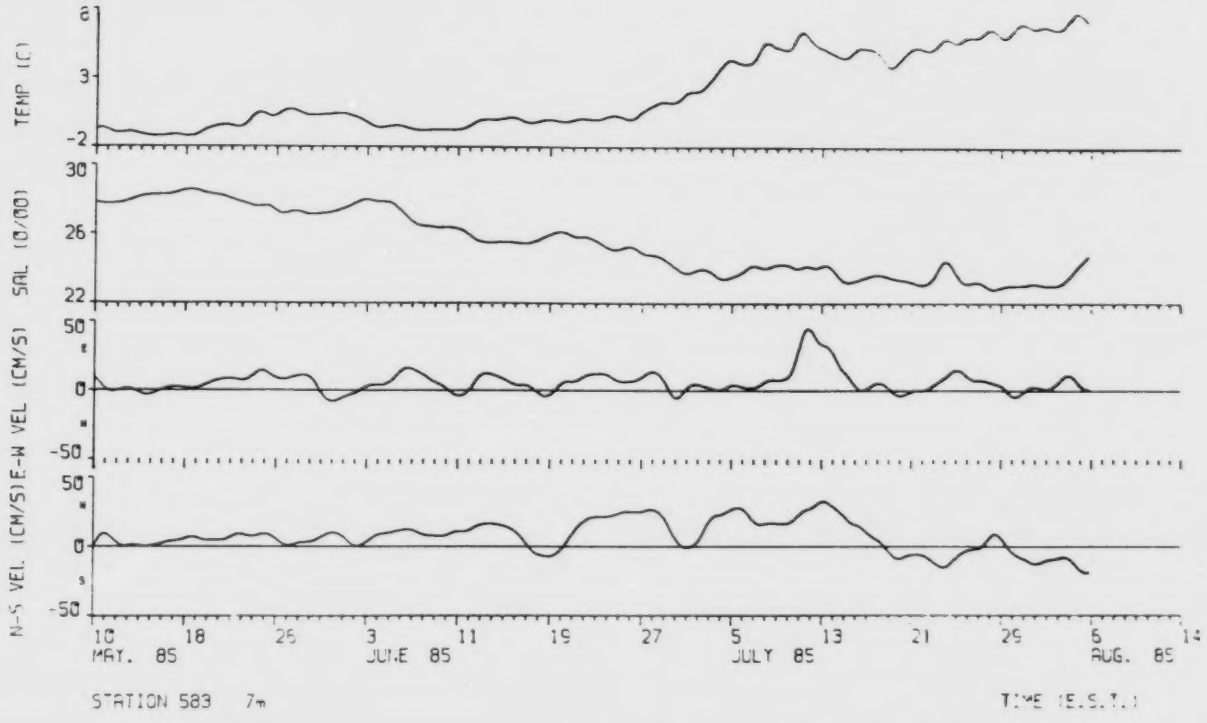


Figure 3. Current meter data collected at 7 m depth at station 583 in 1985.

substantially modified except for an increase in the northern component amplitude of the mean flow. One exception occurred over the July 11–14 period when extreme current values were recorded in the easterly direction. This event was not as marked at station 31. Otherwise, general characteristics at both stations were similar.

In 1986, the only mooring line recovered to date was located at station 583 with instruments at 10 and 58 m depth. Unfortunately, due to a premature firing of the acoustic release the instruments began to drift on June 17. This short record, however, shows the effect of increasing freshwater input in late May-early June. At 10 m depth, salinity gradually lowered from 27 to 25°/oo (Fig. 4). Although the temperature increased slightly, it remained below 0°C. At 58 m depth, a similar pattern was observed, but the difference in temperature and salinity between May 22 and June 16 was very small (Δ T = 0.2°C and Δ S = −0.6°/oo). The mean north-easterly current observed at 10 depth doubled throughout the sampling period, while the south-westerly flow at 58 m was slightly diminished. Both the 1985 and 1986 records show the influence of meteorological forcing in the 3 to 7 day frequency band.

Surface salinity values obtained from the 1986 CTD surveys between May 15 and June 16 gave an interesting picture of time variability in the horizontal plume structure. During the survey of May 26–27, salinity values at the furthest stations were below 5°/oo. Stations 31 and 583 were regularly surveyed between May 27 and June 12. At station 583, salinity increased from 2°/oo to 8°/oo while at station 31, values always remained low (< 1.5°/oo). The survey of June 15–16, although ice floes were present everywhere in the area, show a marked plume contraction in horizontal extent (Fig. 5).

Discussion

The 1986 CTD data suggest that the Great Whale plume had its maximum extent in the early days of June. While the proximal portion (~50 km^2) of the plume did not vary much, remaining low in salinity during the breakup, the distal portion was largely modified by increasing spring runoff. At stations where salinities between 10 and 25°/oo were observed in late April-early May, surface waters were betwen 2 and 4°/oo in mid June (Fig. 5). In July-August, surface salinity in this coastal area is at ambient SSS of about 23°/oo.

In the underlying water, salinity maxima occur in late May, when river runoff is at a maximum and mixing due to direct wind forcing is still low. Stability of the proximal plume is high at that time due to a large density difference between surface and underlying water. By June, although freshwater input is maximal due to combined river and melt water, the distal portion of the plume becomes unstable and the pycnocline is destroyed. Additional energy is provided by direct wind stress through broken ice and higher velocities. Entrainment of saltier water in the surface layer and increased mixing was then initiated. The influence of direct wind forcing was seen on June 3, 1986, with a southerly wind gusting to 50 km h^{-1}. A CTD profile taken in open water conditions, some 2 km to the north of station 31, showed a surface

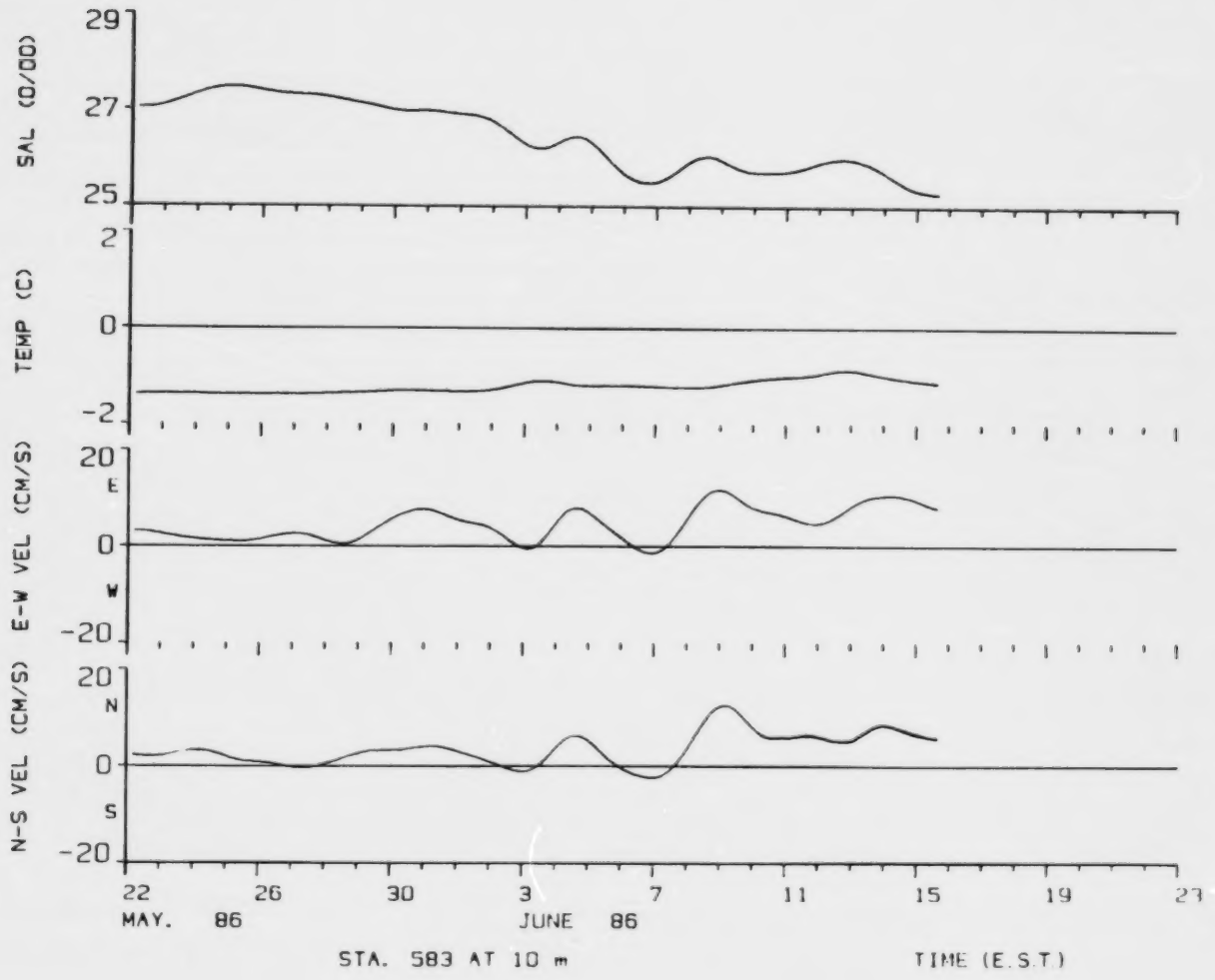


Figure 4. Current meter data collected at 10 m depth at station 583 in 1986.

salinity of over 10°/oo. Similar values were not seen again in the area during breakup.

One can advance the idea that freshwater accumulates under the ice during late winter. If one takes the salinity value 25°/oo as the limit of the plume extension in winter, data collected in 1983 suggest that the enclosed volume of brackish water would be approximately 4×10^9 m^3 in late March and over 6×10^9 m^3 in early May (Larouche, 1984b). The difference in volume is of order 2×10^9 m^3. During that period, total freshwater input of about 10^9 m^3 comes mainly from river runoff since ice melt is initiated only in late May. There is little under-ice vertical mixing because of the weak ambient circulation and high buoyancy. The freshwater is slowly diluted by the Hudson Bay surface waters as it is advected along the coast. An additional source of freshwater in Great Whale area may be that from James Bay located to the south. Winter discharge at La Grande River in James Bay is 20 times that of Great Whale since the completion of the LG 2 power station and may influence water mass characteristics of south-eastern Hudson Bay.

At the end of breakup, freshwater input diminishes and direct wind stress continues to increase so that plume contraction is accelerated. By mid July, the plume collapses to its summer configuration.

Collecting data in a period of intense modifications such as the ice breakup is of primary importance to complete our knowledge of the oceanographic processes in coastal areas where winter icing largely modifies the dynamics of the upper layer.

Acknowledgments

We thank all who helped in collecting the data. Particularly, J.C. Deguise, P. Peltola, D. Lachance and N. Têtu. Also, Joshua Sala our Inuk Guide in Kuujjuarapik. Financial support was provided by the Natural Sciences and Engineering Research Council of Canada (R.G.I.), Donner Canadian Foundation, the Department of Indian and Northern Affairs (S.L.), les fonds FCAR and Fisheries and Oceans Canada (Québec).

References

Danielson, Jr, E.W. 1971. Hudson Bay ice conditions. Arctic 27(2):90–106.
Freeman, N.G., Roff, J.C. and Pett, R.J. 1982. Physical, chemical

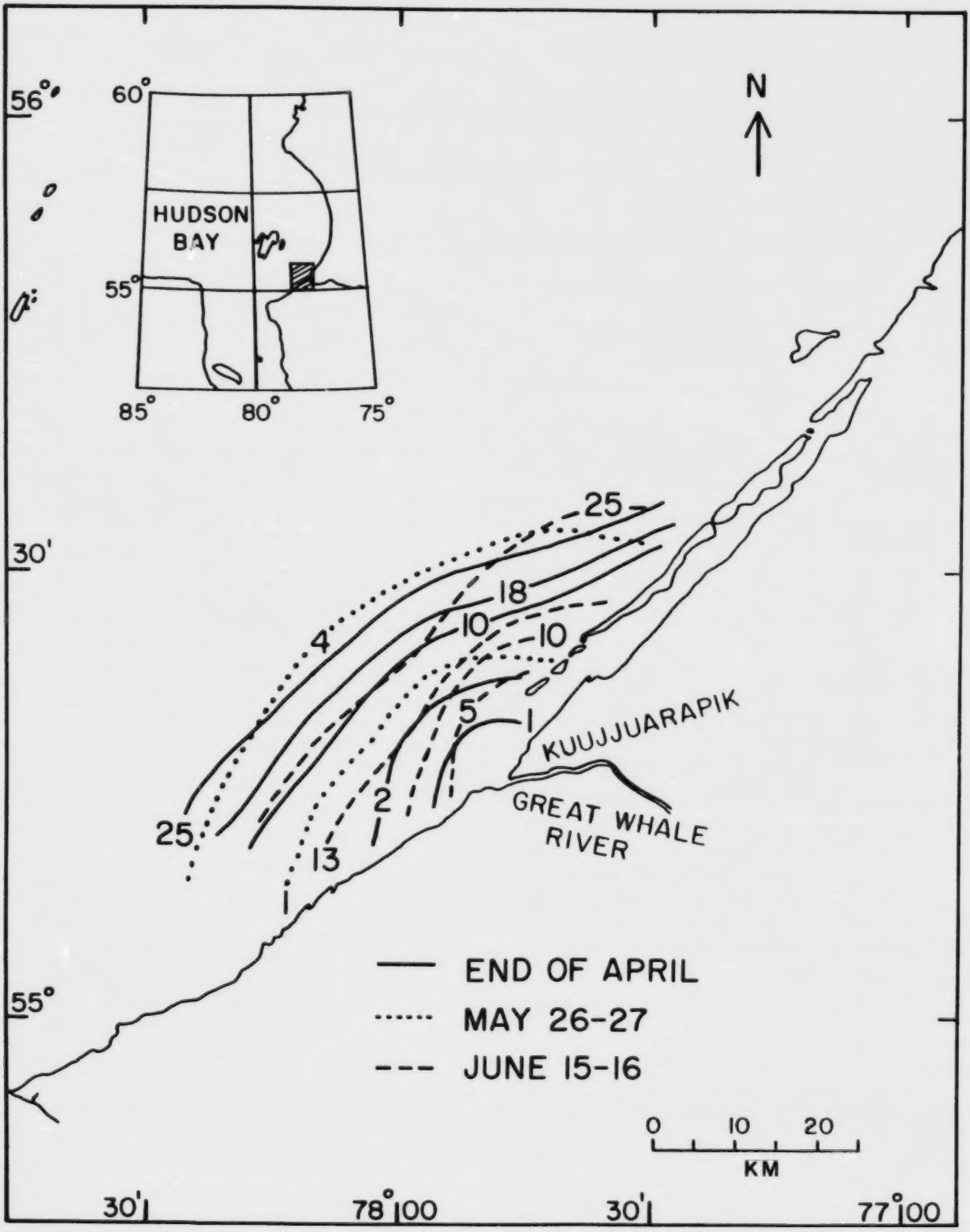


Figure 5. Surface isohaline pattern during 1986 ice breakup.

and biological features of river plumes under an ice cover in James and Hudson Bays. Naturaliste Canadien. 109:745-764.
Godin, G. 1972. The Analysis of Tides. University of Toronto Press. Ontario. Canada. 264 p.
Godin, G. and Barber, F.G. 1980. Variability of the tide at some sites in the Canadian Arctic. Arctic. 33(1):30-37.
Gosselin, M., Legendre, L., Demers, S. and Ingram, R.G. 1985. Response of sea-ice microalgae to climatic and fortnightly tidal energy inputs (Manitounuk Sound, Hudson Bay) Canadian Journal of Fisheries and Aquatic Sciences. 42(5):999-1006.
Hachey, H.B. 1935. The circulation of Hudson Bay water as indicated by drift bottles. Science. 82:274.
Ingram, R.G. 1981. Characteristics of the Great Whale river plume. Journal of Geophysical Research. 86(C3):2017-2023.
Ingram, R.G. 1982. Mean and tidal circulation of the Eastmain river estuary (James Bay). Naturaliste Canadien. 109:733-743.
Ingram, R.G. and P. Larouche. 1987a (in press). Variability of an under-ice river plume in Hudson Bay. Journal of Geophysical Research.
_____ 1987b (in press). Changes in the under-ice characteristics of the La Grande River plume due to discharge variations. Atmosphere-Ocean.
Larouche, P. 1984a. Mesures océanographiques dans le panache de la Grande Rivière de la Baleine, hiver 1982. Rapport statistique canadien sur l'hydrographie et les sciences océaniques no. 19:259p.
_____ 1984b. Mesures océanographiques dans le panache de la Gande Rivière de la Baleine, hiver 1983. Rapport statistique canadien sur l'hydrographie et les sciences océaniques no. 20:711 p.
Legendre, L., Ingram, R.G. and Poulin, M. 1981. Physical control of phytoplankton production under sea ice (Manitounuk Sound, Hudson Bay). Canadian Journal of Fisheries and Aquatic Sciences. 38(111):1385-1392.
Legendre, L., Ingram, R.G. and Simard, Y. 1982. Aperiodic changes of water column stability and phytoplankton in an arctic coastal embayment, Manitounuk Sound, Hudson Bay. Naturaliste Canadien. 109:775-786.
Lepage, S. 1984. Salt intrusion and circulation changes in the Eastmain River estuary, James Bay, subsequent to a large reduction of the fresh water discharge. M. Sc. Thesis. McGill University. Montréal. Canada.
Lepage, S., Couture, R. and Savard, J.P. 1985. Synthèse des conditions estuarienne de la Grande Rivière (1973-1984). Volume 1. Océanographie physique et biochimique. Rapport soumis à la S.E.B.J. par le Groupe-Conseil Roche Ltée. 286 p.
Pett, R.J. and Roff, J.C. 1982. Some observations and deductions concerning the deep waters of Hudson Bay. Naturaliste Canadien. 109:767-774.
Prinsenberg, S.J. 1980. Man-made changes in the freshwater input rates of Hudson and James Bays. Canadian Journal Fisheries and Aquatic Sciences. 37(7):1001-1010.
Prinsenberg, S.J. 1982. Time variability of physical oceanographic parameters in Hudson Bay. Naturaliste Canadien. 109:685-700.
Prinsenberg, S.J. 1983. Effects of hydroelectric developments on the oceanographic surface parameters of Hudson Bay. Atmosphere-Oceans. 21(4):418-430.

ALTÉRATION DES SUBSTRATS ROCHEUX ET RÔLE DU SOULÈVEMENT GÉLIVAL DANS LA FORMATION DE CHAMPS DE BLOCAILLE EN HUDSONIE

Yves Michaud[1] et Jean Claude Dionne[2]

[1] *Department of Geological Sciences, Queen's University, Kingston, Ontario K7L 3N6*
[2] *Département de géographie et Centre d'études nordiques, Université Laval, Ste-Foy, Québec G1K 7P4*

Niveau: Y. Michaud, Doctorat

Résumé

Depuis la déglaciation (7500 ans BP) et le retrait de la mer de Tyrrell, les cuestas hudsoniennes sont soumises aux agents d'érosion périglaciaires. Les surfaces rocheuses composées principalement de basalte, de dolomie et d'arkose, montrent, en moyenne, un pourcentage d'altération de 27%. Bien que la gélifraction soit le processus dominant, le soulèvement gélival a retenu l'attention en raison de son originalité et de son intensité. Ce mécanisme responsable de la formation des soulèvements rocheux périglaciaires joue aussi un rôle significatif dans la formation de champs de blocaille. Dans le secteur du golfe de Guillaume-Delisle, dans une aire de 16 km^2, plus de 1800 édifices de soulèvement gélival ont été observés, ce qui donne, en moyenne, 110 soulèvements/km^2. Les formes d'éjection ont été regroupées en quatre grandes catégories: monolithes, monticules, chaos et édifices à dépression centrale. Le volume de débris impliqués dans les soulèvements est important. Il concourt à la destruction des substrats rocheux au même titre que la gélifraction et la gélidisjonction. Dans le secteur étudié, plus de 25 000 m^2 de surface rocheuse ont été détruits par le soulèvement gélival depuis la déglaciation. Comme les fragments éjectés demeurent sur place, il en résulte des champs de blocaille. La manifestation du phénomène requiert une surface rocheuse abondamment fissurée et saturée en eau ainsi que l'existence de cycles gel-dégel de grande amplitude. Le pergélisol jouerait aussi un rôle dans leur formation.

Mots-clés: Soulèvement gélival, soulèvement rocheux périglaciaires, roche en place, pergélisol discontinu, Hudsonie, météorisation.

Abstract

Since the deglaciation (7500 Y BP) and the retreat of the Tyrrell Sea, the eastern Hudson Bay cuestas are influenced by frost weathering processes. 27% of the surface of the volcanic-sedimentary formations mostly composed of basalt, dolomite and arkosic rocks has been weathered. Obviously, frost action is the main process in this region. Among the weathering processes, frost-heaving is most important because of its intensity. In the Guillaume-Delisle area, more than 1800 frost-heaved bedrock features have been observed in a 16 km^2 area, giving a density of 110 features/km^2. Frost-heaved bedrock features have been grouped into four categories: monolith, dome-shaped structure, chaotic structure and crater-like structure. Aside from frost-shattering and frost-wedging, the bulk of detritus involved in frost-heaving is very important contributing to the destruction of the glacially sculptured bedrock surface. Since the deglaciation in the area, more than 25 000 m^2 of the bedrock surface have

been destroyed by frost-heaving only. The fragments produced by frost-heaving contribute to block field development. The occurrence of this phenomenon requires a densely fractured and water-saturated rock surface, as well as numerous severe freeze-thaw cycles. Moreover, the presence of permafrost is likely to play a role in their development.

Key words: Frost-heaving, periglacial rock upthrust, rock in place, discontinuous permafrost, Hudsonia, weathering.

Note: Paper accepted for publication in *Géographie Physique et Quaternaire de 1987*, Vol. 4, No. 1.

CALIBRATION AND USE OF LANDSAT DATA IN SUBARCTIC TERRAIN ANALYSIS, RUBY RANGE, YUKON TERRITORY

Joan E. Moulton and Steven E. Franklin

Department of Geography, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X9

Level: J. Moulton, Master's

Abstract

In remote, less developed areas of the Earth such as the Canadian North, rugged and mountainous terrain can sometimes make traditional methods of terrain survey and classification based on aerial photography difficult. Landsat imagery offers a valuable alternative for land-cover and ecological classifications. These data can be used to monitor changes over time and as basic inventory and assessment inputs. However, spectral response patterns observed by Landsat sensors do not represent true physical values of surface reflectance as a result of variations in the data caused by sensor calibrations, the atmosphere, and the topography of the reflecting surface. In this paper an unsupervised classification of an area in the Ruby Range, Yukon Territory is presented with class labels based on field observations and the conversion of original digital numbers to approximations of albedo. By calculation of reflectance for Landsats 2–5 on the nine unsupervised terrain types, the importance of using a relatively simple calibration procedure is demonstrated for certain types of image analysis including multitemporal classification and comparing two images for different dates for change detection.

Key words: Landsat multispectral classification, reflectance, southwest Yukon.

Résumé

Dans les régions excentriques et assez peu développées du globe terrestre, tel le Nord canadien, les méthodes traditionnelles de détermination et de classification des terrains, basées sur l'étude des photographies aériennes, sont parfois inopérantes quand il s'agit de régions montagneuses et accidentées. Les images prises par les Landsats constituent alors une option valable pour la classification écologique, et celle de la couverture végétale. On peut utiliser ces clichés pour surveiller l'évolution chronologique de ces facteurs, compiler des inventaires de base et établir des évaluations. Cependant, la répartition de la sensibilité spectrale des capteurs des Landsats ne fournit pas les valeurs véritables de la réflectance des états de surface, en raison des variations de l'étalonnage de ces capteurs, de la transparence de l'atmosphère et du relief de la surface réfléchissante. Dans sa communication, l'auteur présente une classification non suivie d'une région de la chaîne Ruby, au Yukon, en utilisant des désignations tirées d'observations sur le terrain, et il illustre la conversion des données numérisées en valeurs approximatives de l'albedo. Grâce au calcul de la réflectance, mesurée par les Landsats 2–5, de neuf types de terrain non suivis, il met en évidence l'intérêt d'une méthode d'étalonnage relativement simple dans certains genres d'analyse d'images, y compris la classification multitemporelle et la détection des changements comparatifs de deux clichés pris à des dates différentes.

Mots-clés: Classification multispectrale Landsat, réflectance, Sud-est du Yukon.

Introduction

Computer analysis of Landsat imagery has great potential for resource survey and terrain analysis in high mountain regions of the Arctic. Multispectral classification, for example, can provide valuable information regarding the spatial distribution of terrain types because different terrain types vary in reflectance in the different regions of the electromagnetic spectrum sensed by Landsat. These differences are recorded as spectral response patterns and can be efficiently analysed by computer. Accurate maps of the distribution of terrain types are crucial for understanding and interpreting physical values such as the reflectance or albedo of mountain slopes, and that analysis, in turn, may be critical in ecological studies of high relief, high variability subarctic environments. When contemplating a monitoring program using multiple satellite data sets, it is important that the data be made directly comparable through radiometric calibration, otherwise, the resulting maps of terrain features may be inaccurate and their interpretation may be misleading.

The main objectives of this paper are i) to present a preliminary remote sensing classification in the Ruby Range, Yukon Territory and ii) to illustrate the conversion of Landsat digital numbers to physical values such as reflectance. In this research, the calculation of physical values will use the mean digital value of the various landcover classes provided by an unsupervised classification. Known reflectance values are used to calculate the corresponding digital numbers that would be recorded on each of the five Landsat satellites based on calibration information for each satellite. Significant variation in these digital numbers can be used to illustrate the importance of converting the digital numbers to physical values when employing images in the same classification that have been acquired by different satellites.

This study was designed to follow the method of Robinove (1982) who showed the importance of computation of physical values from Landsat digital data as a proper and consistent use of the remote sensing imagery. Due to the complex nature of atmospheric and topographic effects on the Landsat digital numbers and the limited scope of this study, the values used in this analysis will be approximations. The importance of correcting for the other scene-dependent variables will be investigated in future work.

Figure 1. Study Area — Aishihik Lake, Ruby Range, Yukon Territory.

Study area and data collection

The study area, located within the Ruby Range of the Southwest Yukon near Aishihik Lake, is illustrated in Figure 1. The area, one of a series of Mesozoic grandiorite — schist plateaux stretching north from the St. Elias Mountains is characterized by rugged and mountainous terrain as a result of glacial action during the last (Wisconsin) ice maximum and modern fluvial erosion. The maximum elevation reaches approximately 7300 m while minimum elevations are lower than 3000 m. This region has been identified as an Environmentally Significant Area (ESA) by Theberge *et al.* (1980).

During field investigations within the area in 1983, 1984, and 1986 by an interdisciplinary research team, it was noted that slope and relief are environmental gradients that have an important role in describing the spatial arrangement and internal homogeneity of integrated land units. In the valleys, the dominant vegetation is white spruce, but with increasing elevation, a mixed woodland cover containing poplar is present (Franklin and LeDrew, 1984). Alpine shrub cover is found with interspersed willow and dwarfed spruce up to approximately 1500 m in elevation; and above, alpine meadows, tundra and barrens. Although the ecosystem structure is relatively simple, there is great variability in the spatial arrangement of these systems which is intricately linked to topography.

The satellite imagery used in this analysis was acquired 28 August 1978, on Landsat 2 orbit 18324. The scene represents a late summer vegetation phenology with a sun elevation of 33 degrees and an azimuth of 151 degrees. The image was provided with the CAL2 radiometric processing option by the Canada Centre for Remote Sensing (Murphy, 1979). This ensures that the detectors in each band are calibrated to reduce radiometric striping. A subarea 800 pixels and 801 lines was selected to reduce processing time for the analysis while still providing a wide variety of terrain classes. The scanning device was a Multispectral Scanner (MSS) subsystem which uses an oscillating flat mirror to scan cross-track swaths of 185 km in width (Strome et al, 1975) generating imagery in four different parts of the electromagnetic spectrum with a ground resolution of approximately 80 metres.

Methodology

Image classification was performed on a Dipix ARIES III system using an unsupervised strategy (Letts, 1978). The unsupervised method produces classes based on natural groupings or clusters inherent in the data set (Robinove, 1981) as opposed to the supervised strategy where the analyst identifies sample of pixels known to represent certain terrain types. The unsupervised approach was the most appropriate strategy for this research because it was desirable to identify classes that are statistically distinct; in addition it was felt that prior knowledge of the region was too poor to enable a successful supervision of classes. The classification was performed using a maximum-likelihood classifier (Goodenough, 1976). The main output is a simplification of the original image in the form of a thematic map (Fig. 2).

While the unsupervised classification separates the pixels within the image into spectral classes that represent variations in land cover, these classes remain to be identified. Therefore, the next step was to study the classes produced by the unsupervised classification and to describe them in terms of the features they represent on the ground. This was accomplished by taking the unsupervised classification into the field and observing the correspondence between map classes and ground feature types.

The mean digital values in each of the map classes were converted to reflectance values. The formula for calculating reflectance in a single band for a Lambertian surface is after Robinove (1982, p. 782):

$$Reflectance = \left(\frac{PI}{Esinx}\right)\left(\frac{DN}{Dmax}\right)(Lmax - Lmin) + Lmin$$

where

Dn = the digital value of the pixel from the CCT;
Dmax = the maximum digital number recorded on the CCT; (255 for CCRS generated tapes);
Lmax = radiance measured at detector saturation (in mW cm^{-2} sr^{-1});

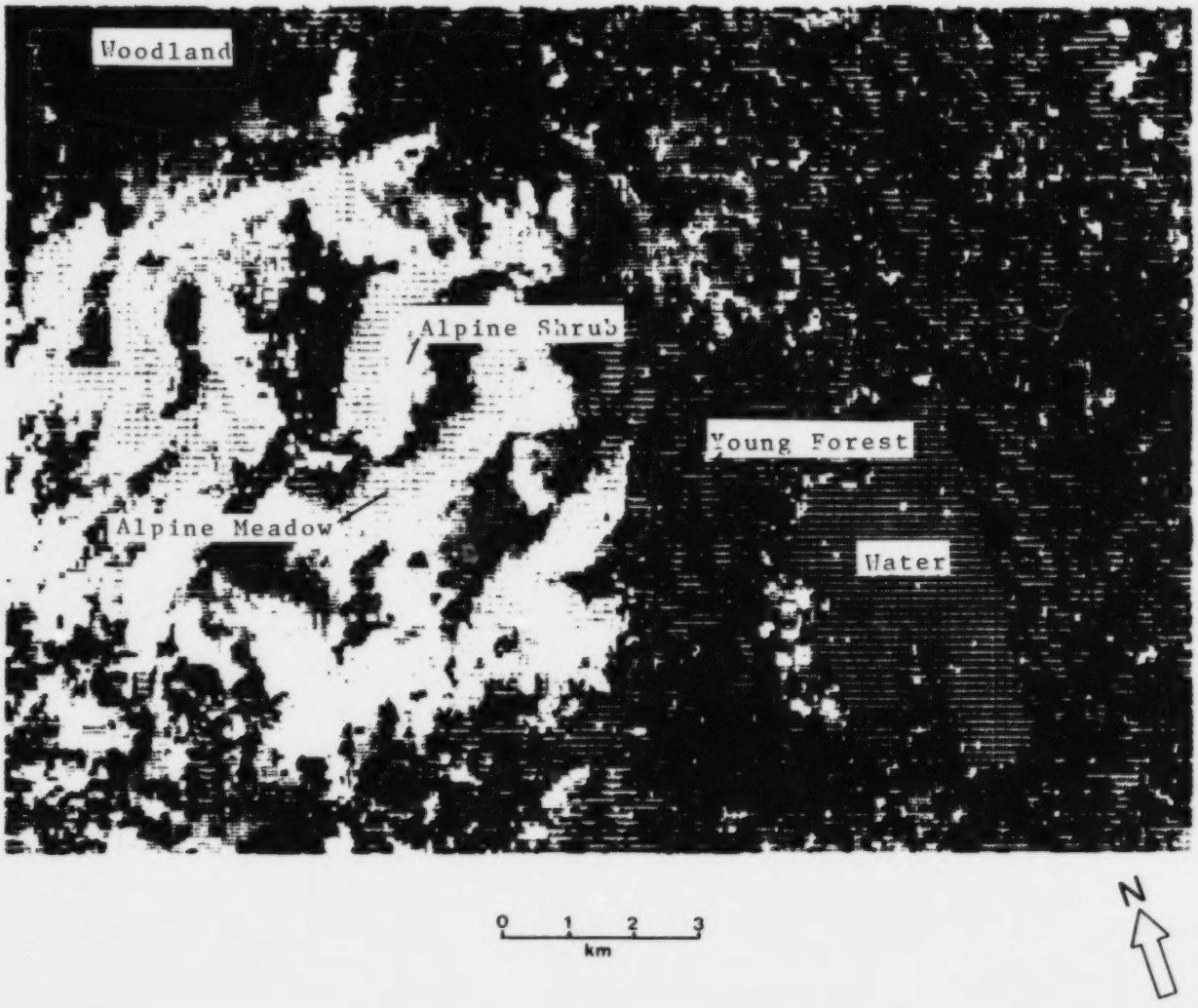


Figure 2. Annotated Subarea of Landsat MSS unsupervised classification. Originally the complete classification was produced in colour. However, for black-and-white publication, a subarea was enlarged so that the spatial distribution of selected classes could be illustrated.

Lmin = lowest radiance measured by the detector in mW cm^{-2} sr^{-1}).

E = irradiance in mW cm^{-2} at the top of the atmosphere:

Band 4 = 17.70 mW cm^{-2}
Band 5 = 15.15 mW cm^{-2}
Band 6 = 12.37 mW cm^{-2}
Band 7 = 24.91 mW cm^{-2}

x = solar elevation, measured from the horizontal as annotated on Landsat images

Calibration information, Lmin and Lmax, for tapes processed at CCRS under the CAL2 option are given by Ahern and Murphy (1978, p. 15) and Murphy (personal communication, Canada Centre for Remote Sensing, Ottawa, 1986).

The method used by Robinove (1982) to reveal significant variations in the pixel values for a scene in western Utah was to compare directly the digital number and the calibrated physical values. If reflectance is used, the analyst will have approximations of albedo which are more meaningful and can be used without relative scales. In order to study the effects of variations in the calibration of different satellite sensors, the reflectance values that correspond to a selected terrain type (Alpine Meadow) calculated from the Landsat 2 digital numbers, were used to calculate the digital numbers that would be recorded on each of the other Landsat satellites. (Reflectance values could have been selected for any of the terrain types). Spectral response curves were then plotted showing the digital number response over the four bands with curves for each of the satellite digital numbers and reflectance values on the same graph (excluding Landsat 1 due to lack of calibration data).

TABLE 1
Unsupervised Classification Class Descriptions

Class	Terrain Type	Description
1	Alpine Meadow	grasses, sedges, forbs, lichens and mosses; less than 10% shrub cover, 5-20% rock outcrops
2	Alpine Barrens	greater than 70% exposed rock grasses.
3	Alpine Shrub	deciduous dominant, greater than 40% shrub cover, shrub height greater than 1m, primarily hazel with some willow.
4	Subalpine Shrub	deciduous dominant, shrubs 0.5-3m primarily quaking aspen, well drained lower mountain slopes;
5	Woodland	20-30% tree cover, tree height greater than 2m, white spruce dominant, mixed deciduous shrubs of willow, hazel and poplar.
6	Young Forest	greater than 40% tree cover height 5-10m, white spruce dominant, lacking understory and shrub layer.
7	Mature Forest	tree cover greater than 25%, height 15-30m, white spruce dominant, poplar understory, deciduous shrubs, valley bottom and lower mountain slopes.
8	Alpine Tundra	bryoid mat consisting of lichens, mosses, woody plants less than 40% deciduous shrub cover less than 25% exposed soil
9	Water	

TABLE 2
Mean Digital Numbers and Calibrated Reflectance Values.

	Band 4		Band 5		Band 6		Band 7	
Class	DN	Ref	DN	Ref	DN	Ref	DN	Ref
1	26.11	0.111	32.67	0.106	75.21	0.229	77.70	0.294
2	26.30	0.112	33.54	0.108	66.50	0.206	68.06	0.260
3	23.91	0.104	29.29	0.097	64.87	0.201	67.11	0.257
4	22.61	0.100	26.96	0.091	56.51	0.179	57.32	0.223
5	20.79	0.094	23.59	0.083	47.86	0.156	47.31	0.189
6	19.32	0.089	20.85	0.076	37.50	0.128	35.64	0.148
7	17.90	0.084	18.35	0.069	26.50	0.099	22.01	0.102
8	26.62	0.113	33.79	0.109	60.37	0.189	60.60	0.235
9	13.25	0.069	10.17	0.049	70.71	0.217	27.59	0.121

TABLE 3
Digital Number Variations for Landsats 1-5 — Class 1

Band	Ref	Landsat1	Landsat2	Landsat3	Landsat4	Landsat5
Band 4	0.111	35.07	26.11	31.21	35.91	32.53
Band 5	0.106	35.42	32.67	32.08	34.45	37.84
Band 6	0.229	71.08	75.21	72.50	91.20	78.80
Band 7	0.294		77.70	70.62	76.36	82.36

— calibration data not available

Results and discussion

An annotatd subarea of the Landsat MSS unsupervised classification and descriptions of each spectral class acquired during field investigation are provided in Figure 2 and Table 1 respectively. Since the classes were not supervised, they represent a statistical division of the study area into homogeneous units which can be assumed to be a suitable generalization of the terrain phenomena contributing to the spectral response pattern. At specific locations in the field, the research team measured terrain phenomena such as percent vegetation cover, density, soil moisture and colour, lithology, slope, and aspect. The analyst must use the field knowledge to name and label the classes. Through this process, a measurable conclusion as to the utility of the image can be made. Most analysts rely on the relative digital numbers and their spatial arrangements in this labelling exercise. In the present study, a transformation of digital values to reflectance is used to supplement the information available.

Table 2 shows the mean digital value of each terrain class produced by the unsupervised classification and the calculated reflectance values. Not only are the reflectance values more correct in the physical sense, but they are more understandable to the scientist than the original digital numbers. For example, very low reflectance values of 0.069 and 0.049 in band 4 and band 5 of spectral class 9 are much easier to visualize as a surface with high absorption in this region of the spectrum, such as water, than the corresponding digital numbers, 13.25 and 10.17 which must be interpreted relatively. In the case of class 1 (alpine meadow) a high reflectance of 0.29 in the infrared portion of the spectrum is more meaningful for interpretation than the relative digital number of 77.

Table 3 contains the known reflectance values derived from the unsupervised classification and digital numbers that have been calculated based on calibration information for Landsats 1-5. In some cases this variation is quite large. For example, Figure 3 visually illustrates this variation for values reprsentative of spectral class 1, described as Alpine Meadow. These results show that there are differences in the way digital numbers vary with wavelength interval and the way reflectance values vary. Variations exist in digital numbers recorded by different satellites. These are a result of differences in the calibration of sensors which have not been corrected for in the digital number data set. They are important in terms of analysis of Landsat digital imagery because changes in spectral response cannot be attributed completely to the differences in terrain phenomena contributing to the spectral response pattern observed by the satellite sensor. Consequently, spectral signatures that are developed for each terrain type based on the data values from operations between spectral channels or from different satellites will not be precise except when only internally consistent, single source imagery are used. The sensor calibrations described here for the Ruby Range, Yukon image become important when comparing or using images from two different dates or when ratioing bands within a single scene. For example, if Landsat data were employed to monitor albedo or other indexes of overall reflectivity in arctic terrain (as they have in arid lands, cf. Musick, 1986) some degree of standardization will

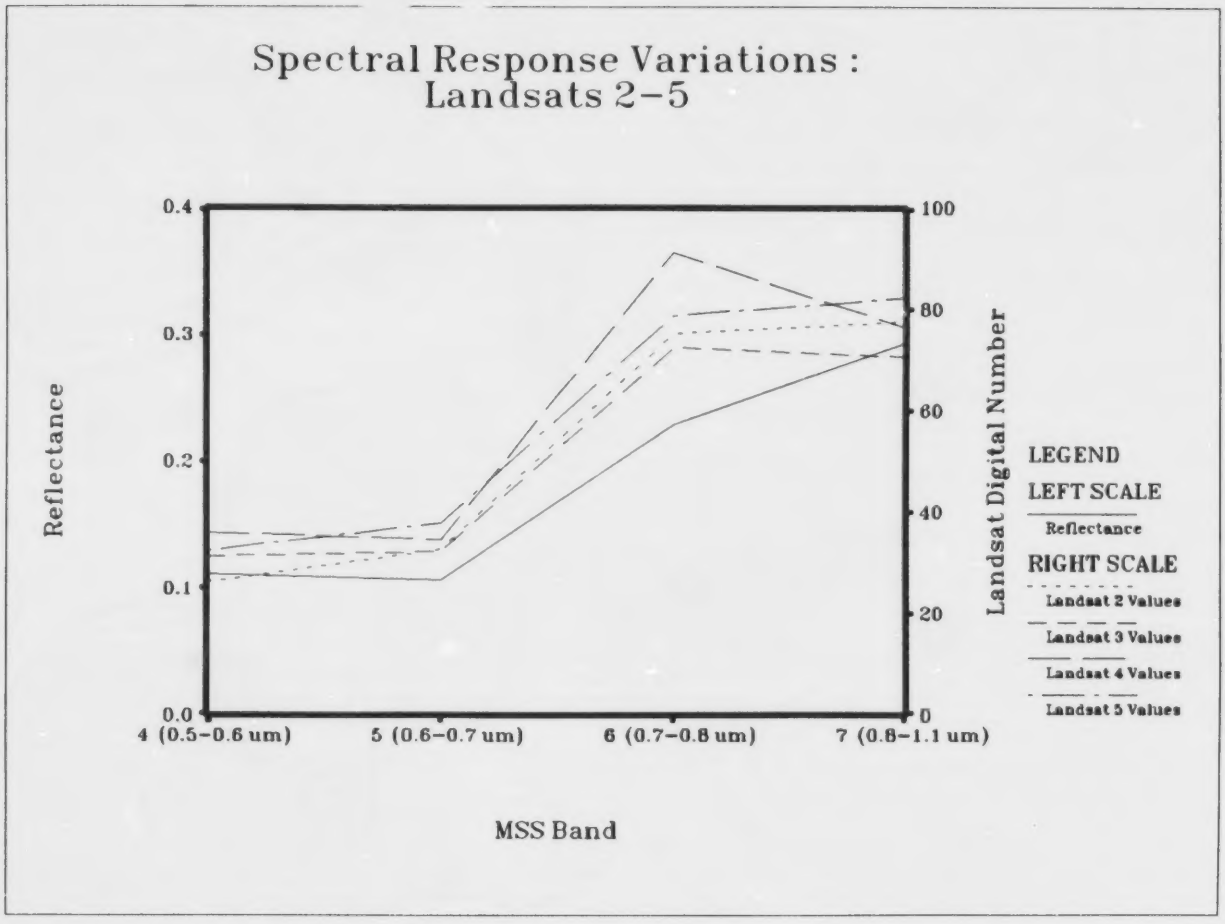


Figure 3. Spectral response curve showing variations in Landsat digital numbers for the same reflectance values. These variations exist because there are variations in the calibration of sensors on different satellites.

be required in these data. Otherwise, comparisons between multiple Landsat data sets could produce misleading and incorrect results.

Summary

This research has illustrated the conversion of the original Landsat data to physical values where the actual terrain reflectance has been calculated and corrected for systematic variables in the data collection and processing system. But, further work is required in the areas of data correction such as atmospheric absorption, atmospheric scattering, and the radiance effects of nearby pixels. Only by employing corrections for these effects can true measures of reflectance or albedo be obtained and more complex image analysis techniques be applied. Classification, such as the unsupervised method described here for a study site in the Canadian Subarctic, could then be performed based on earth surface data alone rather than the earth-atmosphere system. As these remote sensing data become more widely available and are used in new applications the value of standardization of system related inconsistencies will be noticed and applied routinely.

Acknowledgments

Financial and logistical support was provided by the Natural Sciences and Engineering Research Council of Canada, the Canada Centre for Remote Sensing Technology Enhancement Program and the computer facility at Newfoundland Oceans Research and Development Corporation (NORDCO) Limited through the Provincial Department of Development and Tourism. Additional support was provided by Memorial University of Newfoundland and the Department of Indian and Northern Affairs supported the field component. The authors acknowledge the important work of Charles Robinove and are grateful to the anonymous reviewer who provided many helpful coments.

References

Ahern, F.J. and Murphy, J. (1978). Radiometric Calibration and Correction of Landsat 1, 2, and 3 MSS Data (Tech. Rep. 78-4). Ottawa: Canada Centre for Remote Sensing.

Franklin S.E. and LeDrew E.F. (1984). An assessment of information from DEM variables and Landsat MSS data for an area of high relief. Proceedings of the Ninth Canadian Symposium on Remote Sensing. St. John's, Newfoundland, 451-460.

Goodenough, D. (1976). Image 100 Classification methods for ERTS scanner data. Canadian Journal of Remote Sensing, 5(1),18-29.
Letts, P. (1978). Unsupervised classification in the ARIES Image Analysis System. Proceedings of the Fifth Canadian Symposium on Remote Sensing. Victoria, British Columiba, 61-71.
Murphy, J. (1979). Format Specifications for Canadian LANDSAT MSS System Corrected Computer Compatible Tape (Tech. Rep. 79-2). Ottawa: Canada Centre for Remote Sensing, 71 p.
Musick, H.B. (1986). Temporal change of Landsat MSS Albedo estimates in arid rangeland. Remote Sensing of Environment, 20(2),107-120.
Robinove, C.J. (1982). Computation with physical values from Landsat Digital Data. Photogrammetric Engineering and Remote Sensing, 48(5),781-784.
Robinove, C.J. (1981). The logic of multispectral classification and mapping of land. Remote Sensing of the Environment, 11(3),231-244.
Strome W.M., Vishnubhatla, S.S., and Guertin, F.E. (1975). Format Specifications for Canadian LANDSAT MSS System Corrected Computer Compatible Tape (Tech. Rep. 75-3). Ottawa: Canada Centre for Remote Sensing, 64 p.
Theberge, J.B., Nelson, J.G., and Fenge, T. (1980). Environmentally Significant Areas of the Yukon Territory. Ottawa: Canadian Arctic Resources Committee. 134 p.

PHOTOSYNTHETIC ACTION SPECTRA OF ARCTIC ICE ALGAE, RESOLUTE BAY, N.W.T., NOVEMBER, 1986

Robert Palmer, Marlon R. Lewis
Department of Oceanography, Dalhousie University, Halifax, Nova Scotia B3H 4J1

Level: R. Palmer, Bachelor's

Abstract

The photosynthetic action spectrum, as defined as the slope of the photosynthesis-irradiance curve at low light, was determined spectrally (every 25nm from 400 to 675nm; 25nm half-maximum bandpass) for ice algal populations under different conditions of ambient light caused by variations in depth of snow cover. Maximum photosynthetic rate was relatively constant for each wavelength in all snow depths. The action spectra varied in a manner consistent with adaptation of the photosynthetic unit. Spectra were typical in shape to those from other ocean diatom populations, with a strong peak at 450nm due to chlorophyll *a*. The amplitude of the spectra was different under different snow cover and reflected adaptation to the different ambient light levels. Implications of these results for the primary productivity of the ice algal population in the Canadian High Arctic are discussed.

Key words: Ice algae, photosynthesis, action spectra.

Résumé

L'auteur a tracé le spectre d'activité photosynthétique des algues nivales, défini comme la pente de la courbe de photosynthèse/rayonnement en faible éclairement, en effectuant les mesures tous les 25 nm, de 400 à 675 nm, bande passante demi-maximale de 25 nm, dans différentes conditions d'éclairement, fonction de l'épaisseur de la couche nivale. Le taux maximum d'intensité photosynthétique s'est révélé relativement constant à chaque longueur d'onde, à tous les niveaux de profondeur. Le spectre d'activité varie conformément à l'adaptation de l'organe photosynthétique. Les spectres étaient similaires à ceux des diatomées océaniques, et montraient une pointe à 450 nm, due à la présence de chlorophylle *a*. L'amplitude des composantes du spectre était inégale et reflétait l'adaptation de l'algue aux différents niveaux d'éclairement ambiant. L'auteur déterminera les conséquences de ces faits pour la productivité primaire du peuplement d'algues nivales dans l'Extrême-Arctique canadien.

Mots-clés: Algues nivales, photosynthèse, spectre d'activité.

Introduction

The epontic algae associated with the ice/water interface in the Canadian High Arctic first appear around March and are dispersed sometime prior to the breakup of the ice pack in late April. During this time the algae are rarely exposed to light levels exceeding 1-2% of that incident on the surface (Cota 1985). Under these low light levels (ca. 15 μEin m^{-2} s^{-1} at solar noon; Platt *et al.*, 1982) these algae have been shown to contribute 30 to 65% of the annual primary production in the Arctic (Alexander 1974, Horner and Schrader 1982, Gosselin *et al.* 1983, Subba Rao and Platt 1985).

The relationship between photosynthesis and light is linear at these intensities with the slope equal to the product of the pigment specific (chlorophyll) absorption and the photosynthetic quantum yield. This product has been found to be the highest measured to date (Cota 1985) for the ice algal population near Resolute Bay, N.W.T. For other species of algae the magnitude and spectral composition of the absorption is not fixed but depends on the intensity and the spectral composition of the light under which the algae are growing (Neori *et al.* 1984, Lewis *et al.* 1985).

Maykut and Grenfell (1975) have shown that maximum transmission through first year sea ice is in the 450-550 nm range regardless of surface conditions or ice thickness and found strong attenuation in the red portion of the spectra. It is the nature of the upper surface which is the dominant factor in determining the amount of energy which penetrates through the ice to the ocean; surface snow depth is the primary attenuation factor for the downward irradiance. Given this spectral filtering, and the low ambient irradiance levels, variability in both the spectral characteristics and absolute magnitude of photosynthesis at low light has profound influence on the primary production of the ice algal layer and hence the productivity of the arctic ecosystem.

Here we attempt to predict the primary productivity under first year sea ice through direct spectral measurements of photosynthetic parameters for the first time, and convolute these with the spectral irradiance reaching the ice algal band.

We then estimate the error in use of the more standard "white light" incubation and the total irradiance in such calculations. Finally, we attempt to evaluate the significance of such measurements to the primary production of the arctic ice algal layer.

Materials and Methods

This study was carried out from May 30 to April 10, 1985 approximately 1 km offshore from Sight Point on the southwestern tip of Resolute Bay, Northwest Territories (70° 40′ N, 94° 54′ W). The depth of the ice at this time was approximately 1.8m thick and samples were obtained under snow cover of 0, 7 and 10.5 cm. The "clear patch" (0cm) was kept relatively free of snow by the daily use of a snow blower.

Algal samples were collected using an auger and an ice chisel. An algal suspension was formed by gently melting the ice fragments in a container in a water bath; this suspension was diluted 4:1 with filtered surface sea water and measurements of photosynthetic action spectra were made using a modified "photosynthetron" (Lewis and Smith, 1983) operating at a temperature of −0.8 C following the technique described in Lewis *et al.* (1985b).

The data were fit to the following empirical relationship between photosynthesis and irradiance (P-I curve) using a nonlinear curve fitting routine:

$$P^B(I,\lambda) = P^B_M(\lambda)\,[\,1 - \exp(-\frac{\alpha(\lambda)\,I(\lambda)}{P^B_M(\lambda)})]$$

where P^B is the photosynthetic rate normalized to unit chlorophyll *a*, $P^B_M(\lambda)$ is the maximal value of photosynthesis at each wavelength, $\alpha(\lambda)$ is the wavelength dependent slope at low light and $I(\lambda)$ denotes the spectral irradiance.

The adaptation parameter ($I_k(\lambda)$) was calculated using the equation:

$$P^B_M(\lambda) / \alpha(\lambda)$$

A tendency towards linearity at some wavelengths necessitated the use of a standard linear regression analysis with slope equal to $\alpha(\lambda)$

Estimates of chlorophyll *a* areal standing crop were provided by Dr. R. Smith (unpublished), and used for the prediction of *in-situ* photosynthesis using spectral transmission data of Maykut and Grenfell (1975).

Measured irradiance at the ice surface and data from Maykut and Grenfell (1975) were used to estimate spectral characteristics of the irradiance incident on the ice algal layers. For example, the extinction due to 10cm of snow (0cm of ice) was estimated at 30% of the total downwelling irradiance and was assumed to be spectrally uniform. Ice extinction values for each wavelength were also obtained from Maykut and Grenfell (1975). Linear interpolations of their figures were used when necessary.

The noon flux on the day of the experiment was used in an effort to predict maximal *in-situ* photosynthesis and was

TABLE I
PI parameters and standard deviations for each snow depth.

Snow depth 0cm :													
	:	WAVELENGTH											
	:	400	425	450	475	500	525	550	575	600	625	650	675
	α	.00584	.00676	.01230	.00655	.00305	.00209	.00210	.00182	.00098	.00158	.00149	.00387
	P^B_m	-	-	-	-	-	-	-	-	-	-	-	-
S.D. in	α	.00049	.00077	.00083	.00048	.00024	.00018	.00013	.00015	.00015	.00016	.00027	.00073

Snow depth 7cm :													
	:	WAVELENGTH											
	:	400	425	450	475	500	525	550	575	600	625	650	675
	α	.00214	.00507	.00692	.00620	.00249	.00217	.00246	.00038	.00197	.00074	.00288	.00144
S.D. in	α	.00165	.00327	.00312	.00122	.00153	.00137	.00124	.00012	.00081	.00009	.00064	.00160
	P^B_m	.01652	.01855	.01991	.02075	.02054	.01942	.02103	-	.01854	-	.01926	.33404
S.D. in	P^B_m	.00563	.00423	.00393	.00165	.00368	.00410	.00398	-	.00279	-	.00203	19.12888
	I_k	7.71963	3.65877	2.87717	3.34677	8.24900	8.94931	8.54878	-	9.41117	-	7.18657	232

Snow depth 10.5cm :													
	:	WAVELENGTH											
	:	400	425	450	475	500	525	550	575	600	625	650	675
	α	.00465	.00519	.00493	.00768	.00376	.00124	.00233	.00162	.00064	.00062	.00086	.00170
S.D. in	α	.00285	.00282	.00258	.00091	.00148	.00049	.00084	.00072	.00009	.00008	.00007	.00018
	P^B_m	.01582	.01594	.01911	.01936	.01930	.02587	.01903	.02191	-	-	-	-
S.D. in	P^B_m	.00403	.00381	.00428	.00099	.00247	.01170	.00263	.00495	-	-	-	-
	I_k	3.40215	3.07129	3.87627	2.52083	5.13298	20.70181	8.16738	13.52469	-	-	-	-

separated into spectral bands using a normalized spectral sea surface irradiance profile. The I (0, λ) values are therefore the amount of light in each wave band reaching the top of the algal layer.

The values for Kc (λ) (m^2/mg) were obtained from the values listed for pigment rich ocean waters (k2 (λ)) in Smith and Baker (1978).

The irradiance penetrating the algal layer, I (z, λ), can be defined as:

$$I(z, \lambda) = I(0, \lambda)\, e^{-K_T(\lambda)\,\ell}$$

where ℓ is the length of the algal band (approximately 0.03m, R. Smith, pers. com.) and Kt (λ) is given by:

$$Kc(\lambda) * B$$

where B is the volumetric concentration of chlorophyll (R. Smith, pers. com.).

The mean irradiance in each wavelength in the algal band is:

$$\bar{I}(\lambda) = I(0, \lambda) * \left[\frac{1}{\ell\, K_T(\lambda)} (1 - e^{-K_T(\lambda)\,\ell}) \right]$$

and the sum of the $\bar{I}$ (λ) values is the total irradiance (PAR) available inside the algal band photosynthesis

TABLE II
In Situ irradiance values.

	I(0,λ)			Ī(z)		
Snow Depth (cm)	0	7	10.5	0	7	10.5
Wavelength (nm)						
400	0.10	0.04	0.03	0.05	0.02	0.01
425	0.91	0.36	0.26	0.52	0.17	0.13
450	1.85	0.72	0.51	1.24	0.39	0.30
475	2.35	1.15	0.84	1.98	0.65	0.49
500	2.78	1.16	0.85	2.13	0.72	0.55
525	2.67	1.12	0.82	2.21	0.79	0.60
550	2.63	1.10	0.81	2.30	0.86	0.64
575	2.06	0.86	0.63	1.86	0.71	0.53
600	1.52	0.64	0.47	1.41	0.55	0.41
625	1.20	0.50	0.37	1.12	0.44	0.33
650	0.79	0.33	0.24	0.71	0.27	0.20
675	0.29	0.12	0.09	0.24	0.09	0.07
Total	19.53	8.17	6.01	15.53	5.44	4.26

I(0,λ) = light in uEin m^{-2} s^{-1} reaching top of algal layer
Ī(z) = mean light in uEin m^{-2} s^{-1} inside the algal layer

To estimate the total productivity under each snow depth, the I (values (Table II) are multiplied by the ∝ values (Table I) and by the areal chl*a* concentration. The result is an estimate of the total integral production of the ice algae on an areal basis (Table III).

Comparison of this spectral estimate with a theoretical "white" light incubation can be made using a normalized irradiance profile to weight an averaged ∝ as measured under "white" light (solar spectrum),

$$\bar{\alpha} = \Sigma\, [\alpha(\lambda) * I^N(\lambda)]$$

which is an estimate of the photosynthetic efficiency under white light in which I^N (λ) represents the normalized irradiance at each wavelength.

TABLE III
Areal chlorophyll and estimated total productivity calculated using the spectral measurements.

Snow Depth	Chl	Production	
(cm)	(mg/m^2)	(ugC/ugChl/h)	(mgC/m^2/d)
0	23	0.057	31.6
7	43	0.016	16.3
10.5	40	0.012	11.4

The mean spectrally-weighted extinction coefficient within the algal band can be defined as follows:

$$\bar{Kc} = \frac{\Sigma\, [Kc(\lambda) * \bar{I}(\lambda)]}{\Sigma I(\lambda)}$$

The total integral production as estimated from a "white" light incubation is then:

$$\int Pdz = \frac{1}{\bar{K_c}} * \bar{\alpha}\, (\Sigma \bar{I}(\lambda)) * [1 - \exp(-K_c \int_0^{\ell} Bdz)]$$

where B is now the areal concentration in mg/m^2 (Tables III and IV).

TABLE IV
Estimated total productivity from theoretical "white" light incubation.

Snow Depth	Production	
(cm)	(ugC/ugChl/h)	(mgC/m^2/d)
0	0.050	27.4
7	0.011	10.9
10.5	0.008	7.5

Results

At snow depths of 7 and 10.5 cm, photosynthesis was predominately a saturating function of irradiance at each given wavelength; this relationship was linear for the clear patch (0 cm) at all wavelengths (Table I).

Exceptions to the nonlinear relationship (denoted by dashed lines in Table I) occurred when the defined value of P_M^B exceeded reasonable limits (approached infinity) or when the curve in question was determined by inspection to be more linear than nonlinear. This subjectivity was only necessary when neither the nonlinear or linear fits produced significantly different results.

The values of ∝ in Table I very between wavelength and between each snow depth. In contrast the values for P_M^B remain relatively constant, approximately 0.02 (+/−.002), for all wavelengths and snow depths of 7 and 10.5 cm.

The slope of the curves (∝ in Table I) in Figures 1–3 when plotted as a function of wavelength determines the action spectra shown in Figures 4A–C.

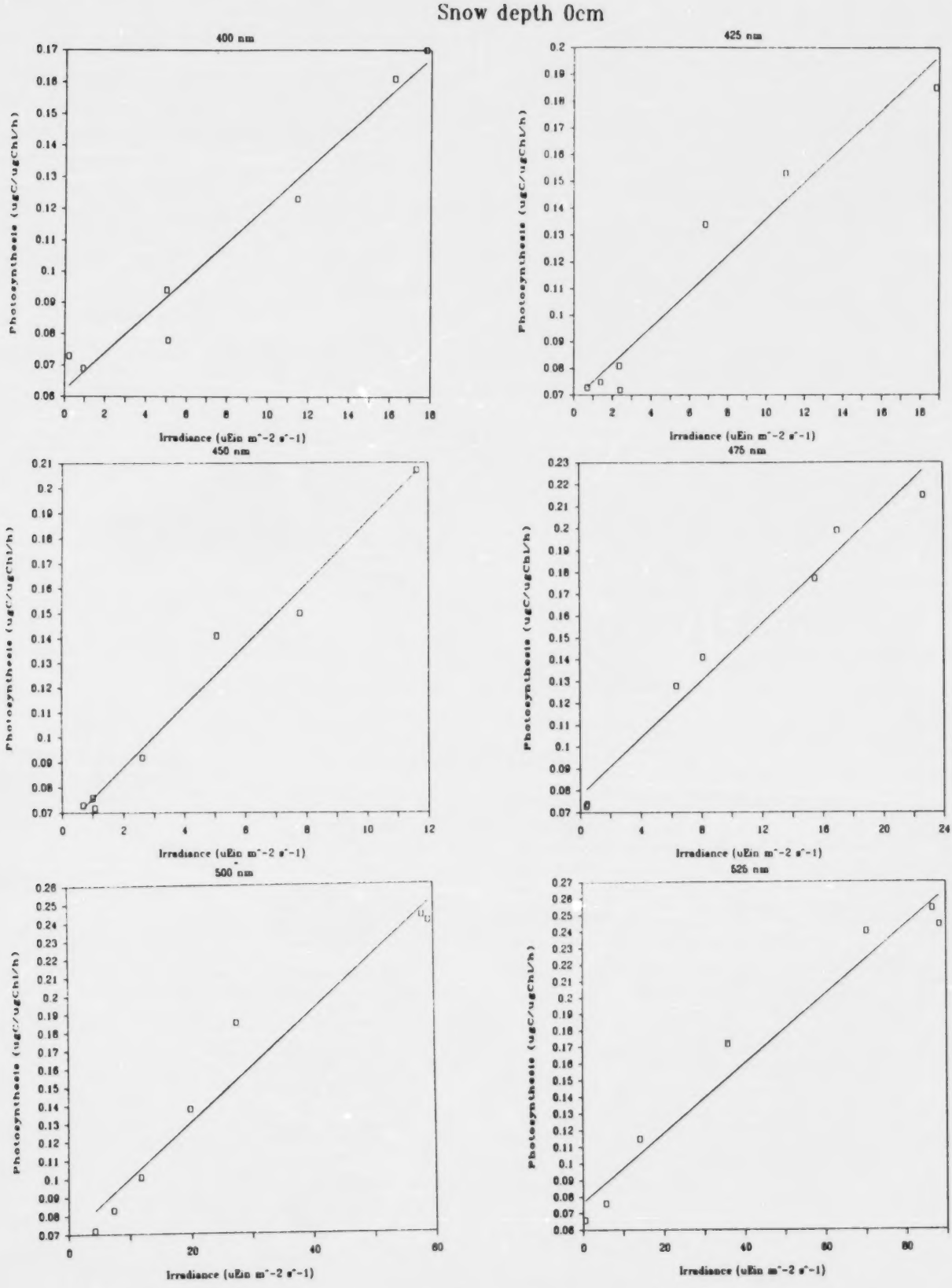


Figure 1. Photosynthetic rate as a function of irradiance at different wavelengths for 0cm of snow cover.

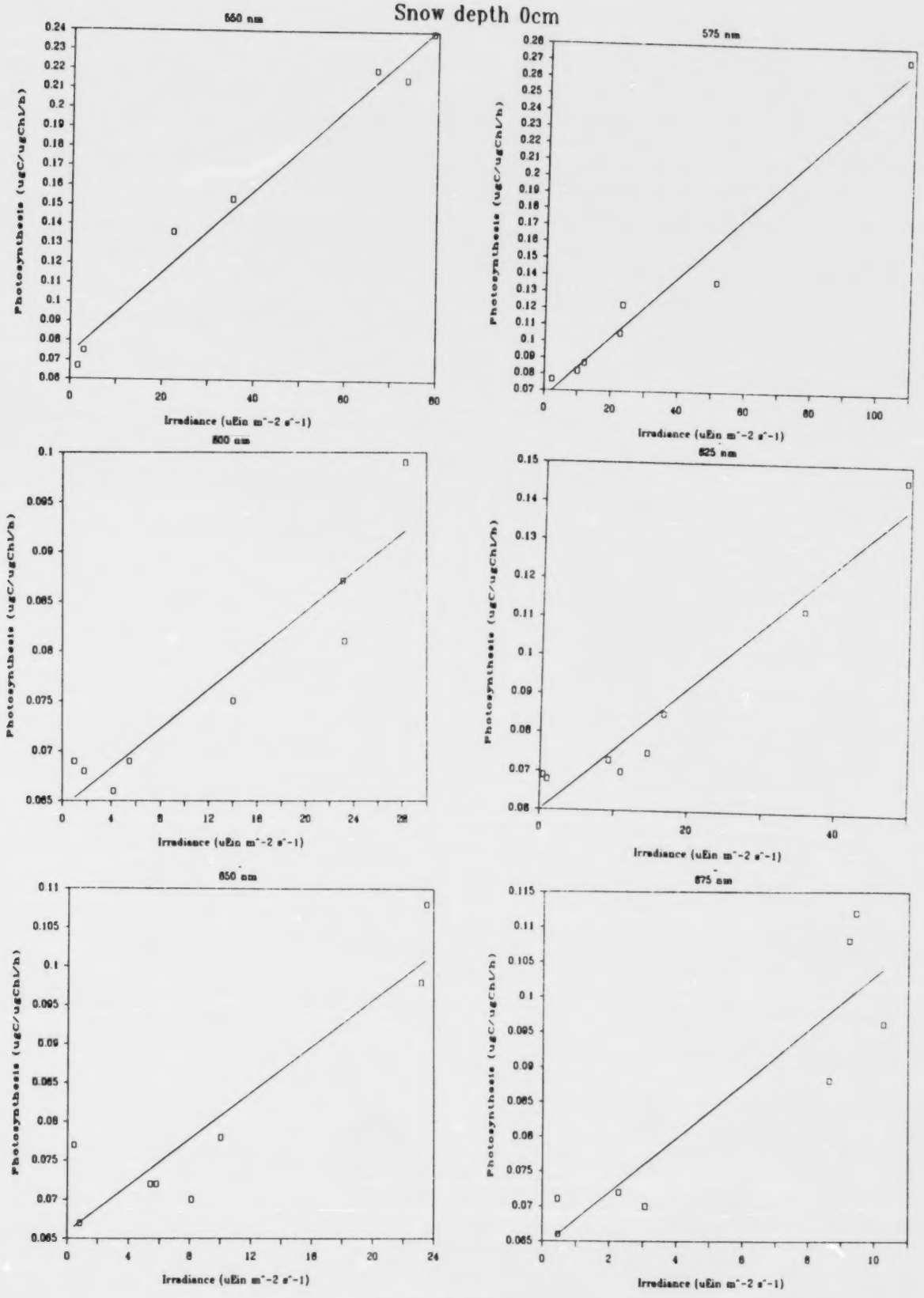


Figure 1. continued.

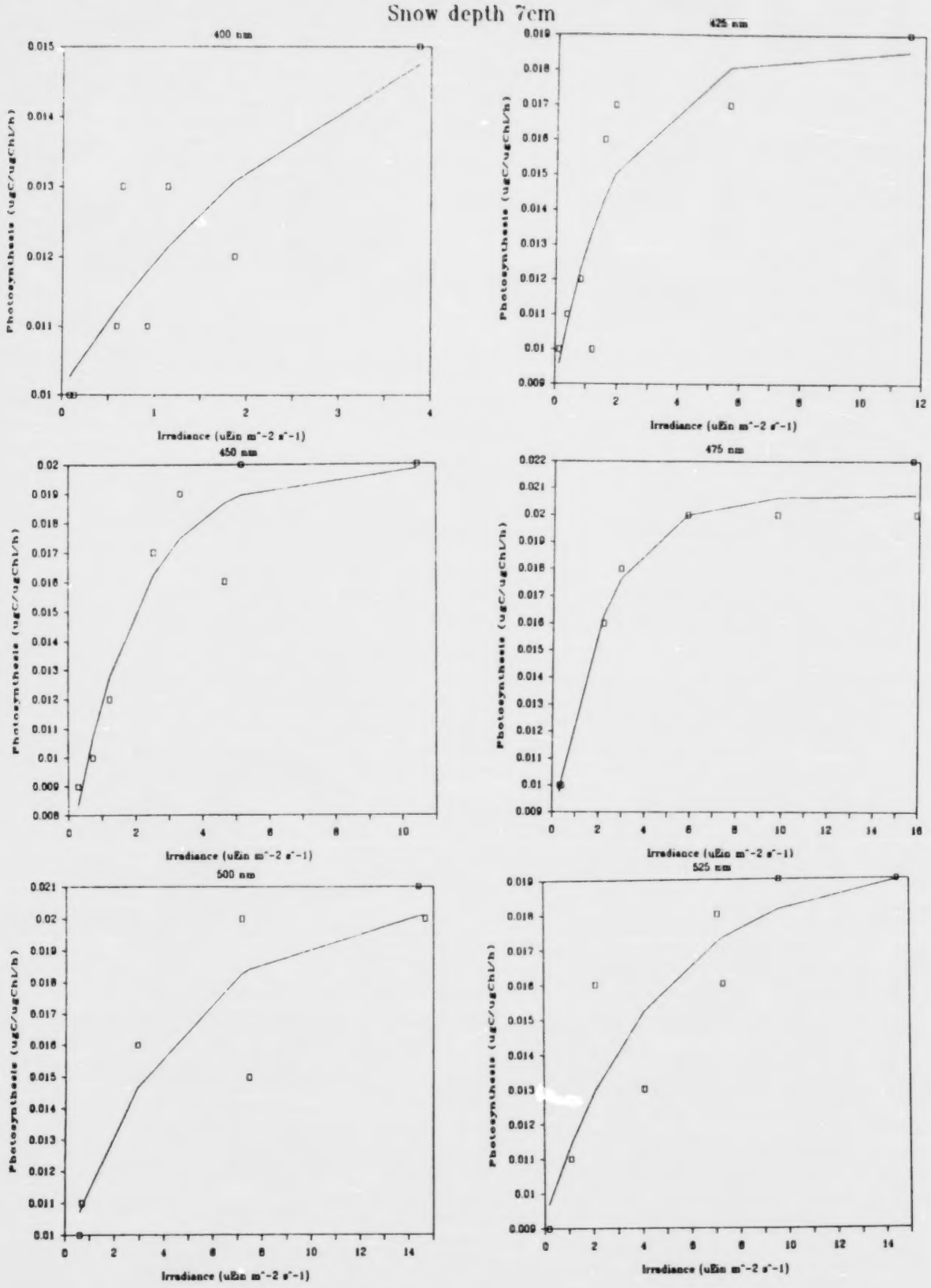


Figure 2. Photosynthetic rate as a function of irradiance at different wavelengths for 7cm of snow cover.

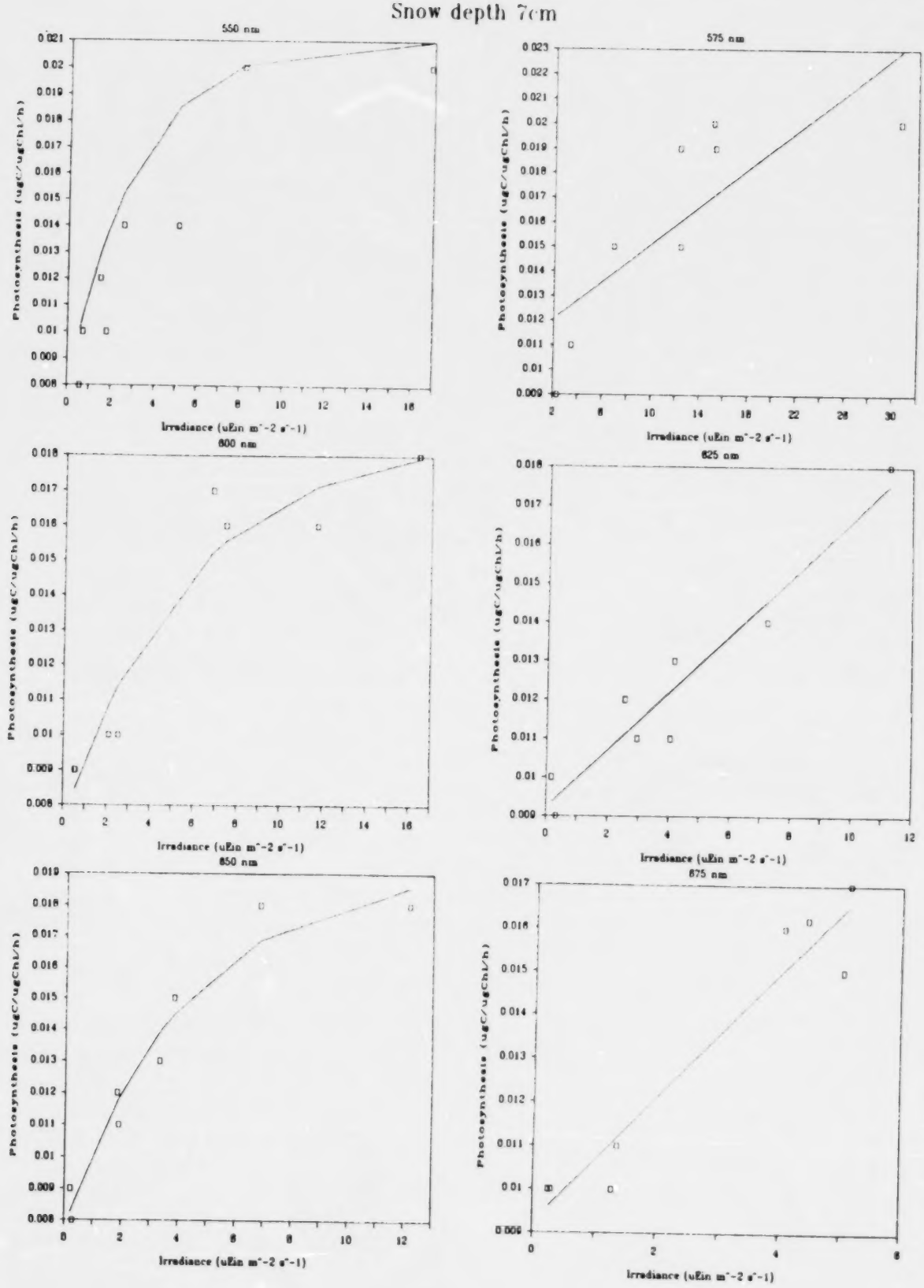


Figure 2. continued.

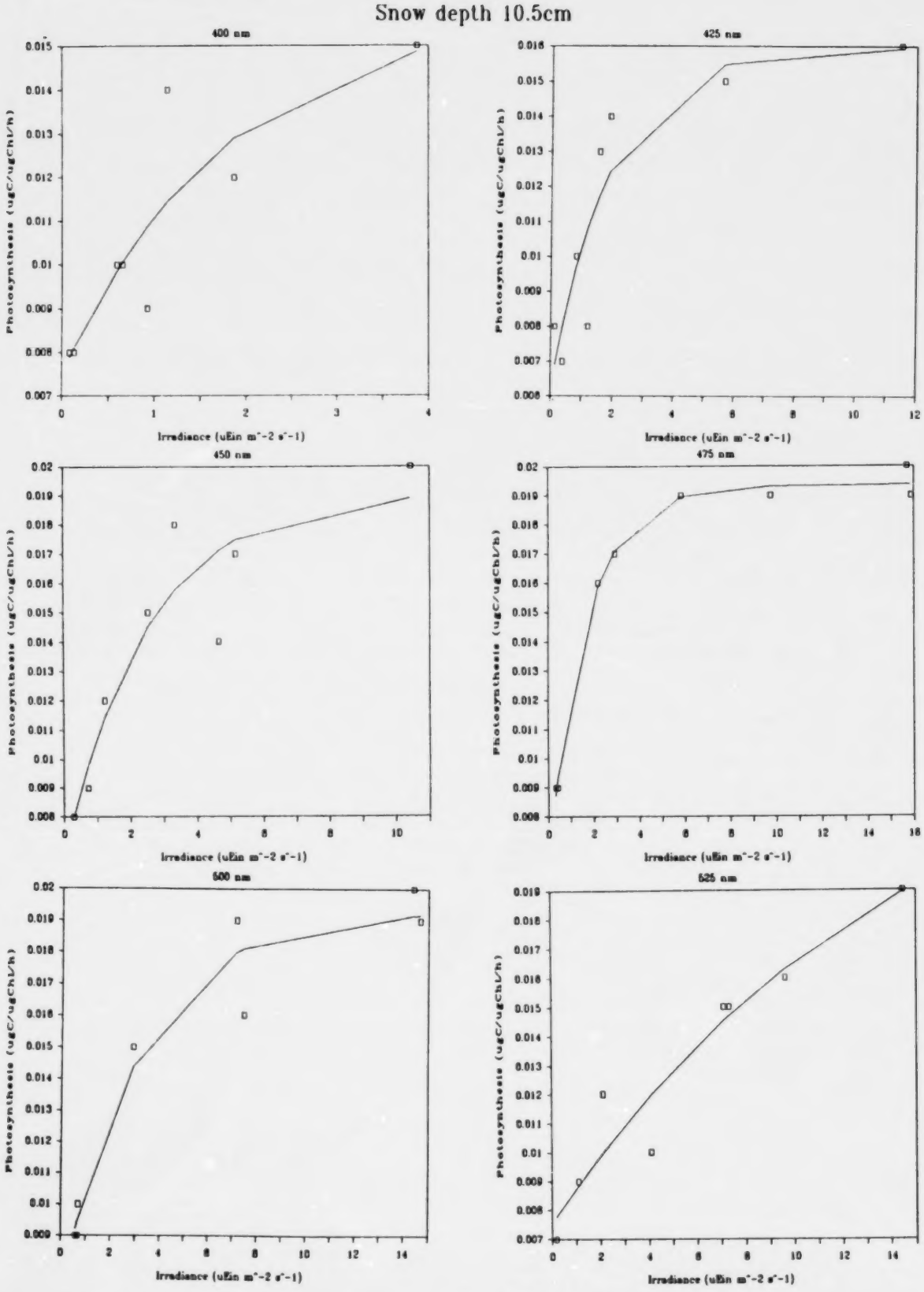


Figure 3. Photosynthetic rate as a function of irradiance at different wavelengths for 10.5cm of snow cover.

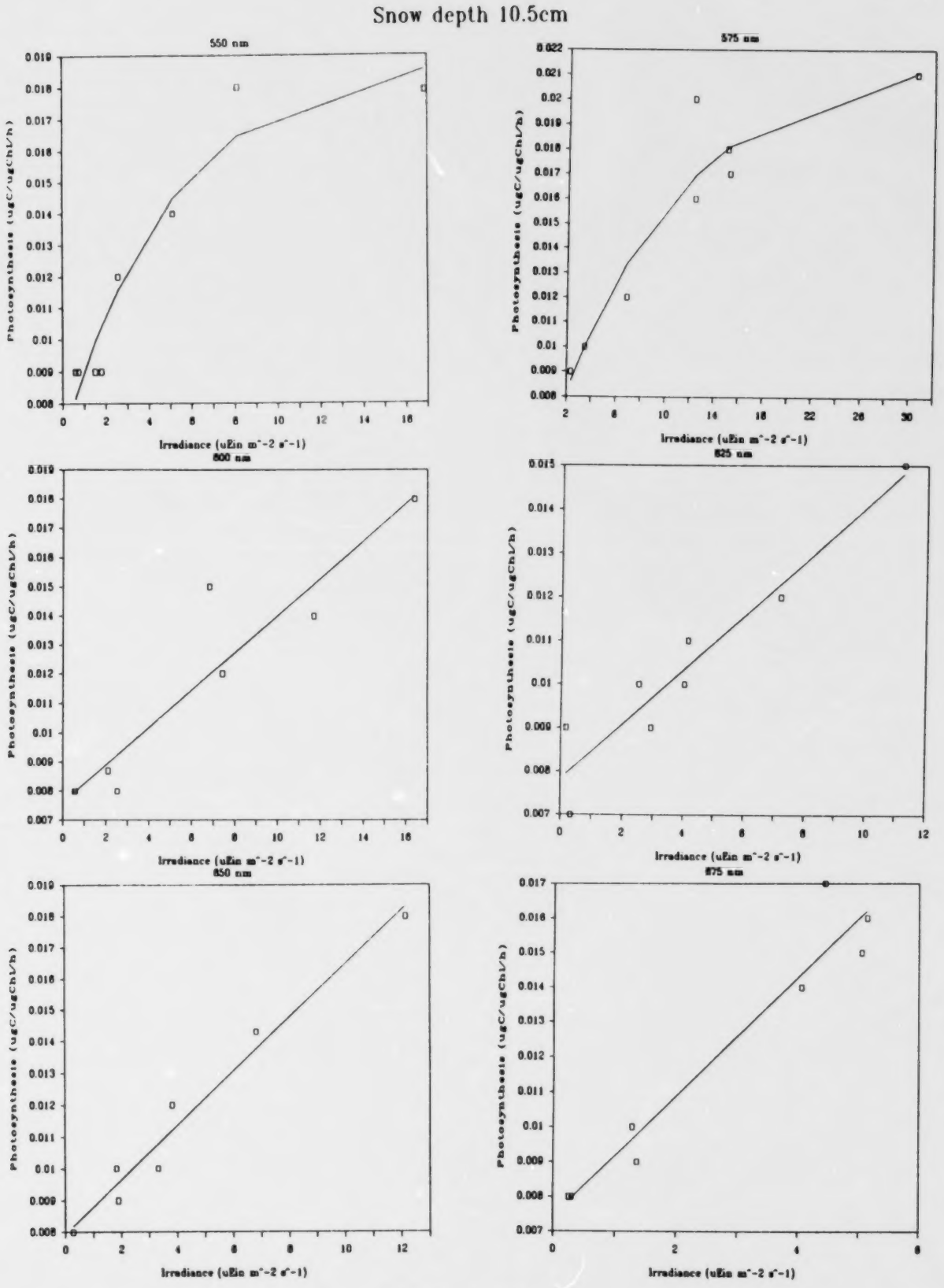


Figure 3. continued.

The spectra for the clear patch (0cm; Figure 4A) peaked at 475nm and then fell off sharply to 550nm then declined more slowly to 600nm after which a slow rise occurs to the final peak at 675nm.

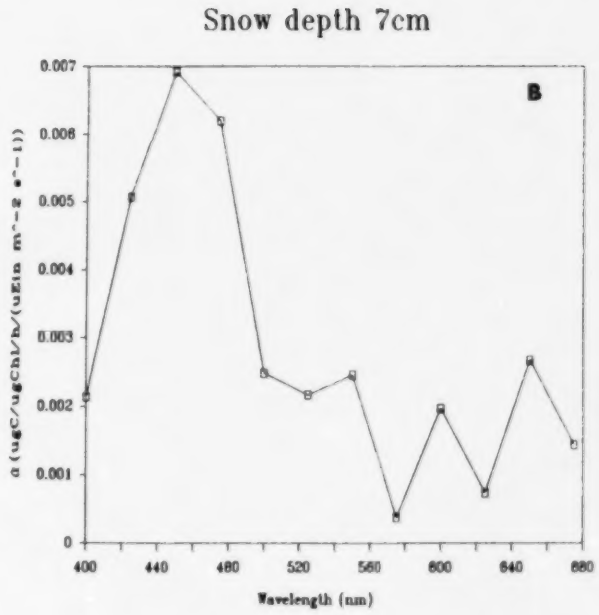
The spectra for 7cm of surface snow cover had a large peak at 450nm whereas under 10.5cm of snow (Figure 4C) a slight rise is noted at 425nm and the peak is at 475nm.

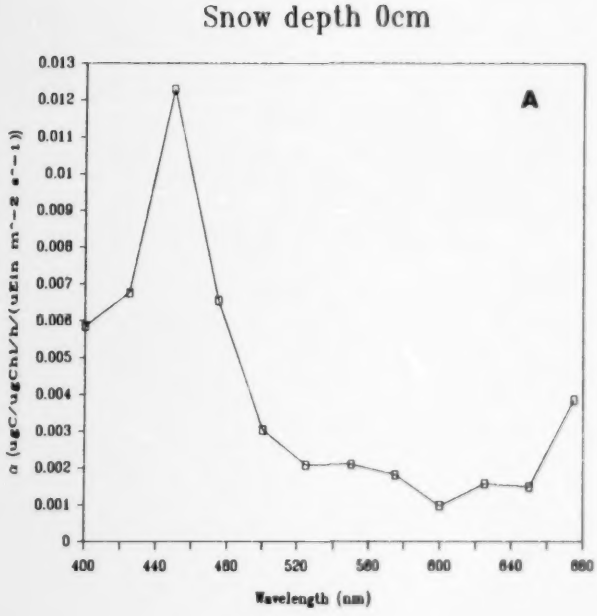
The spectra for the 7cm snow depth drops off sharply from 550nm to 575nm and then fluctuates to peak at 600nm and at 650nm. The spectra for 10.5 cm shows little fluctuation and peaks again at 675nm.

The adaptation parameter (Ik (λ)) was found to be generally less than 10 μEin m^{-2} s^{-1} for all wavelengths in snow depths 7 and 10.5cm (Table I).

The mean light inside the algal layer was 15.83, 5.66, and 4.26 μEin m^{-2} s^{-1} for snow depths 0, 7 and 10.5cm respectively (Table II).

The total integral production as estimated spectrally was 0.057, 0.016, and 0.012 μgC/μgChl/h or 31.6, 16.3, and 11.4 mgC/m^{-2}/d for snow depths of 0, 7, and 10.5cm respectively; however the theoretical values calculated for a "white" light incubation under the same snow cover were 0.05, 0.011, and 0.008 μgC/μgChl/h or 27.4, 10.9, and 7.54 mgC/m^{-2}/d respectively, a difference of roughly 34% for snow depths of 7 and 10.5cm and 13% for 0cm on a per day basis. (Tables III and IV).





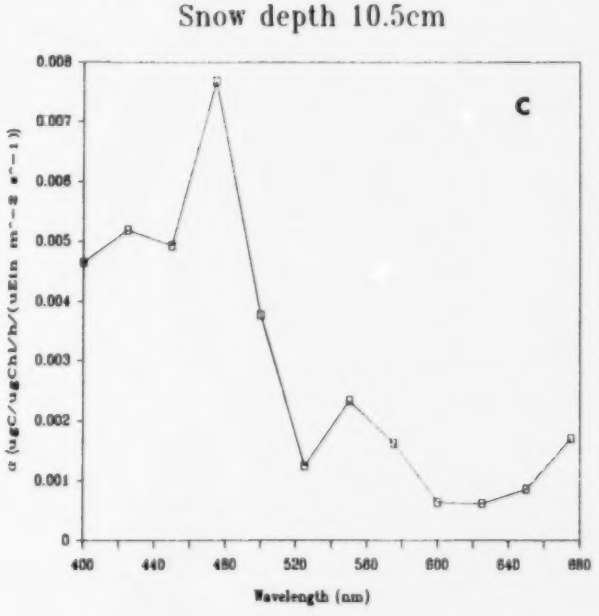


Figure 4. Photosynthetic action spectra for the three snow depths A) 0cm, B) 7cm, C) 10.5cm.

Discussion

The photosynthetic efficiencies, α (Table I), as given by the initial slope of the PI curve (Figures 1-3), decrease with increasing snow cover; however the shape of the action spectra (Figure 4A-C) seems to indicate a shift toward the green portion of the spectrum in the deeper snow depths. Under 0cm of snow the action spectrum (Figure 4A) shows a strong peak at 450nm after which it falls sharply to 525nm. The peak is broader under 7cm of snow cover and only a small drop in α is observed from 450 to 475nm. Under 10.5 cm of snow cover the peak has shifted from 450 to 475nm and the fall to 525nm is again pronounced. Chlorophyll *a* absorbs light at approximately 440nm and 675nm (Prezelin 1981; Parsons *et al.* 1984) and chlorophyll *c* absorbs light between 470 and 490nm (Neori *et al.* 1984). The shift in the shape of the spectra with increasing snow depth may indicate that the ice algae are adapting to the lower light environment under 10.5cm of snow by increasing their absorption cross section through pigment addition, presumably chlorophyll *c* or other accessory pigment addition; however explicit determination of this from these data is not possible. The physiological mechanisms through which this is accomplished in these cells remain unknown and it will be of some interest to discover the time frame through which these ice algae adapt to the constantly changing snow cover on the surface of the ice.

Ice algae are primarily diatoms and therefore contain carotenoid accessory pigments (predominately fucoxanthin) which absorb between 400 and 575nm. Accessory pigments transfer their energy to chlorophyll *a* in the reaction center of the P700 photosystem and are used to increase the energy captured in low light environments (Parsons *et al.* 1984, Prezelin 1981). The shape of the action spectra for 0 and 7cm of snow cover (Figure 4A and B) indicates an increase around 475 to 575nm (relative to chlorophyll *a*) and there is some indication that at 10.5cm of snow this increase has shifted further towards 575nm. These shape changes in the spectra may indicate an increase in carotenoids (relative to chlorophyll *a*) in response to the lower light environment under 10.5cm on snow cover.

The photosynthetic unit (PSU) as discussed by Prezelin (1981) consists of a chlorophyll *a* core surrounded by accessory pigments. This core is considered to be fairly uniform such that changes in PSU size can be shown through changes in amount of light harvesting component (LHC) associated with each PSU. Her model (Prezelin and Sweeney 1979) of photoadaptation shows that as the size of the LHC increases (PSU number remaining constant) Pm/cell remains constant and Pm/Chl *a* decreases in direct proportion with the increased LHC, when cells are grown under low irradiance levels.

Here, P^B_M (λ) decreased slightly from 7 to 10.5cm of snow cover (Table I) in addition P^B_M (λ) is much larger under 0cm of snow cover as the Pi-I curves (Figures 1A-L) did not saturate under similar irradiances consistent with the model proposed by Prezelin and Sweeney (1979).

The data in Table I shows that P^B_M remained relatively constant across wavelengths at 0.02 (+/− 0.002) indicating that the maximum rate of photosynthesis is independent of wavelength between 400 and 675nm for ice algal populations in the Canadian Arctic. Pickett and Myers (1966) found a similar result for *Chlorella* between 450 and 705nm.

Falkowski and Owens (1980) in experiments with the diatom *S. costatum* found that α values decrease as cells become shade adapted. This supports the data presented here as α decreased. The ice algal population under 10.5cm of snow appears to be growing less efficiently, unlike Cota's (1985) conclusion that these algae are shade adapted. The increased chlorophyll which entered the calculation of α at the deeper snow depths may bias this result if a large amount of detrital material was present in the algal layer sampled. Lewis *et al.* (1985a) found a similar result in the Sargasso Sea. If however the chlorophyll values are genuine, the apparent decrease in α may be due to nutrient limitation over the period of sampling. Gosselin *et al.* (1985) and Cota *et al.* (in press) have found that ice algal production is affected by tidal energy as this influences the input of nutrients to the algal layer.

Palmisano *et al.* (1985) could not get a diatom growing in the water column under the ice and ice algae to photoinhibit at 300 μEin m^{-2} s^{-1} so it is unlikely that these ice algal populations are unable to use the light if it becomes available. Work by Dr. R. Smith in the Northwest Passage this spring may also support this (pers. com.).

Maykut and Grenfell (1975) estimated the strength of algal absorption in the Antarctic by measuring under-ice transmittance beneath 125cm of white ice with and without algae. They found the algal transmittance signal to be 540nm. The percent difference between the two transmission spectra was calculated to yield an absorption spectra similar in shape to the action spectra presented here. In addition carotenoid absorption in Figures 4A-C was small relative to chlorophyll and thus is consistent with these authors' high transmittance signal at 540nm.

These values of α can be used to estimate the primary production in the algal layer, taking into account both the spectral dependence in α irradiance, as well as the self-shading associated with the dense flora. Integral production refers to the total photosynthesis in the range of PAR irradiances. Hence convoluting α with the available PAR results in a value for the productivity. These values can be summed across the spectral range of PAR to give integral photosynthesis as estimated by the spectral method used here. Similarly a mean α (see methods) can be defined and used in conjunction with the incoming solar radiation to predict production when spectral data are not available.

In going from 0 to 7 to 10.5cm of snow cover, the mean light diminished from 15.83 to 5.66 to 4.26 μEin m^{-2} s^{-1} but photosynthesis only diminished from 0.057 to 0.016 to 0.012 μgC/μgChl/h thus the algal photosynthesis on a per unit chlorophyll basis appears to follow the decrease in available light. For example there is approximately a four fold decrease in available light from 0 to 10.5cm and a corresponding four fold decrease in production. Production estimates from the theoretical "white" light incubation show a similar trend declining from 0.05 to 0.011 to 0.008 μgC/μgChl/h as snow depth increases from 0 to 10.5cm.

Comparison of integral production values as estimated spectrally with the theoretical values for "white" light on a per unit chlorophyll basis provide only a slight indication that white light estimates of production are somewhat lower than

spectral estimates for populations growing under low irradiance levels. However integral production on a per day basis results in a spectral estimate which is 34% higher than the theoretical estimate under "white" light for snow depths of 7 and 10.5cm and only 13% higher for 0cm of snow. A case can be made for using spectral incubations over the more standard "white" light incubations when dealing with algal populations adapted to low environemental irradiances as the former method provides more defined estimates of $\propto$ for the photosynthetically active region of the spectrum and in so doing allows for a more precise prediction of total production. The data presented here may indicate that for populations adapted to environmental irradiances greater than 16 μEin m^{-2} s^{-1}, use of the spectral method over the "white" light results in no significant difference in the estimation of production. The result is consistent with previous work along these lines (Lewis *et al.* 1985b, Harrison *et al.* 1985).

In summary the estimates of integral primary production of ice algae using the spectral method are somewhat higher than values estimated on a theoretical basis under "white" light indicating that for populations adapted to low irradiances the former method is preferable. The data presented here show that these algae are not more efficient at low irradiances; factors such as nutrient limitation or the presence of detrital matter in the algal layer may influence these results as the shape of the action spectra (Figures 4A–C) appear to indicae pigment addition and hence increasing PSU size when the ice algae are under deeper snow cover.

Acknowledgments

We are greatful to Drs. G. Cota, and S. Bates for their help in the field and to Dr. R. Smith who provided the supplemental data necessary for the *in situ* predictions of primary productivity.

The work was funded by the Natural Sciences and Engineering Research Council Canada and the Department of Fisheries and Oceans through their subvention program.

References

Alexander, V. 1974. In, J.C. Reed and J.E. Sater (eds.). The coast and shelf of the Beaufort Sea. Arctic Inst. N. America 609–632.

Cota, G.F. 1985. Photoadaptation of high Arctic ice algae. Nature. 315:219–222.

Cota, G.F., S.J. Prinsenberg, E.B. Bennett, J.W. Loder, M.R. Lewis, J.L. Anning, N.H.F. Watson, L.R. Harris. 1986. Nutrient flux during extended blooms of Arctic ice algae. J. Geophys. Res., in press.

Falkowski, P.G. and T.G. Owens. 1980. Light-shade adaptation. Two strategies in marine phytoplankters. Plant Physiol. 66:592–595.

Gosselin, M., L. Legendre, S. Demers and R.G. Ingram. 1985. Responses of sea-ice microalgae to climatic and fortnightly tidal energy inputs (Manitounuk Sound, Hudson Bay). Can. J. Fish. Aquatic Sci. 42:999–1006.

Harrison, W.G., T. Platt, and M.R. Lewis. 1985. The utility of light-saturation models for estimating primary productivity in the field: A comparison with conventional "simulated" in situ methods. Can. J. Fish. Aquat. Sci. 42(5):864–872.

Horner, R.A. and G.C. Schrader. 1982. Relative contribution of ice algae, phytoplankton, and benthic microalgae to primary production in near shore regions of the Beaufort Sea. Arctic 35:485–503.

Lewis, M.R., R. Warnock, T. Platt. 1985. Absorption and photosynthetic action spectra for natural phytoplankton populations: implications for production in the open ocean. Limnol. Oceanogr. 30(4):794–806.

Lewis, M.R., R. Warnock, B. Irwin, T. Platt. 1985. Measuring photosynthetic action spectra of natural phytoplankton populations. J. Phycology. 21:310–315.

Lewis, M.R. and J.C. Smith. 1983. A small-volume, short-incubation time method for the measurement of photosynthesis as a function of incident wavelength. Mar. Ecol. Prog. Ser. 13:99–102.

Maykut, G.A. and T.C. Grenfell. 1975. The spectral distribution of light beneath first-year sea ice in the Arctic Ocean. Limnol. Oceanogr. 20(4):554–563.

Neori, A., O. Holm-Hansen, B.G. Mitchell and D.A. Kiefer. 1984. Photoadaptation in Marine Phytoplankton. Plant Physiol. 76:518–214.

Palmisano A.C., J.B. SooHoo, D.C. White, G.A. Smith, G.R. Stanton, L.H. Burckle. 1985. Shade adapted benthic diatoms beneath Antarctic sea ice. J. of Phycol. 21(4):664–667.

Parsons, T.R., M. Takahashi, B. Hargrave. 1984. Biological Oceanographic Processes 3rd edition. Pergamon Press, Oxford. Chapter 3. p. 61–87.

Platt, T., W.G. Harrison, B. Irwin, E.P. Horne, C.L. Gallegos. 1982. Photosynthesis and photoadaptation of marine phytoplankton in the Arctic. Deep Sea Res. 29:1159–1170.

Pickett, J.M. and J. Myers. 1966. Monochromatic light saturation curves for photosynthesis in *Chlorella*. Plant Physiol. 41(1):90–98.

Prezelin, B.B. 1981. Light reactions in photosynthesis, p. 1–43 *In* T. Platt (ed.) Physiological Bases of Phytoplankton Ecology. Can. Bull. FIsh. Aquat. Sci. 210.

Prexelin, B.B. and B.M. Sweeney. 1979. Photoadaptation of photosynthesis in two bloom-forming dinoflagellates. *In* D. Taylor and H. Seliger (eds.) Toxic Dinoflagellate Blooms, pp. 101–106. Elsevier North Holland, Inc.

Smith, R.C. and K.S. Baker. 1978. Optical classification of natural waters. Limnol. and Oceanog. 23(2):260–267.

Subba Rao, D.V. and T. Platt. 1984. Primary production of Arctic waters. Polar Biol. 3:191–201.

THE CONCEPTUAL DEVELOPMENT OF A NEW FORM OF UPWARD-ACTING ICEBREAKER BOW

Bruce Paterson

Ocean Engineering Program, Memorial University of Newfoundland, St. John's, Newfoundland A1C 5S7

Level: Master's

Abstract

A new form of upward-acting icebreaker bow has been developed that incorporates recent advances in icebreaking design. Previous upward-acting designs have taken a plow configuration. The new bow form employs a shearing action which reduces resistance to ice. Design of icebreaking vessels involves a complex analysis of environmental factors, modes of operation, and available technology; minimizing ice resistance is only one consideration. The iteraction of these factors results in an iterative design process which must reconcile the different environmental conditions and available technology, to produce an efficient and reliable vessel for its proposed route. In the context of the broader design problem, the upward-acting icebreaking concept offers significant advantages because the broken ice moves along the hull above the waterline. Drillships, dredges, and floating

production platforms could have their operating season extended because ice is broken upward around the vessels. Specialized hull forms featuring a narrow beam and shallow draft could be designed for larger vessels that may be affected by the shallow harbour depths and prohibitive deepwater port facility costs encountered in the Arctic. Safety and reliability would be enhanced by reducing the frequency of ice impact with hull appendages. While minimizing ice resistance is an important factor, the objective was to produce an upward-acting bow with resistance comparable to a downward-acting bow, because of its important operational advantages. The design process began with a review of recent icebreaking innovations, past upward-acting bow designs, and available icebreaking analyses. The Oil/Bulk Ore Carrier M.V. "Arctic", in level ice conditions, was used as a test case. Five configurations were tested in a small-scale refrigerated towing tank, using a recently developed model ice. These tests demonstrated the feasibility of the concept. Each towing trial was videotaped, and following a series of over 100 tests a configuration was selected for comparative resistance trials against a model equipped with a conventional icebreaker bow, at a scale of 1:30.

Key words: Icebreakers, icebreaking bow, Alex bow, Thyssen-Waas bow, model ice, M.V. "Arctic".

Résumé

On a mis au point une nouvelle forme d'étrave de brise-glace agissant par soulèvement, en incorporant au navire les progrès les plus récents. Antérieurement, ces étraves de soulèvement ressemblaient au double versoir d'une charrue. La forme nouvelle produit un effet de cisaillement qui diminue la résistance de la glace. La conception des brise-glace exige une analyse complexe des facteurs de milieu glaciel, des modes de fonctionnement et des techniques disponibles; la réduction de la résistance de la glace ne constitue qu'un paramètre parmi d'autres. L'interaction de ces facteurs nécessite un processus conceptuel itératif qui doit adapter la technologie disponible en fonction des différents facteurs de milieu, afin de déboucher sur un brise-glace efficace et fiable convenant aux eaux auxquelles il est destiné. Dans un cadre gestionnel plus large, l'étrave de soulèvement des glaces offre des avantages notables par rapport à l'étrave «à la cuiller» qui les pousse vers le bas. On pourrait ainsi étendre la saison de navigation des navires de forage, des dragues et des plateformes flottantes d'extraction pétrolière, grâce à la rupture vers le haut du champ de glace qui les entoure. Il est possible de dessiner des coques de forme spéciale à maître-bau étroit et faible tirant d'eau pour les gros bâtiments, gênés par les eaux peu profondes, et leur éviter les frais extrêmement élevés des ports en eau profonde de l'Arctique. La sécurité et la fiabilité des navires seraient accrues si l'on réduisait le nombre des heurts entre les saillies de la coque et les glaces. Bien qu'il soit important de réduire la résistance de la glace, on s'est efforcé de dessiner une étrave de soulèvement accomplissant un effort comparable à celle de l'étrave «à la cuiller», en raison de ses avantages pratiques importants. Le processus de conception a commencé par un tour d'horizon des innovations récentes en matière de brise-glace, des formes connues d'étraves à soulèvement, et des analyses publiées de l'action des brise-glace. On a utilisé, pour les essais-pilotes, le pétrolier-minéralier Arctic dans un champ de glace plat. Cinq formes ont été touées dans un bassin d'essais réfrigéré de petite taille, en utilisant un modèle de glace récemment mis au point. Les programmes informatiques existants n'offrant pas la souplesse et la précision nécessaires, on a enregistré chaque essai au magnétoscope. A la suite d'une série de plus de cent essais, on a effectué des essais comparatifs de résistance entre le modèle choisi et un modèle au 1/30e de brise-glace équipé de l'étrave traditionnelle.

Mots-clés: Brise-glace, étrave de brise-glace, étrave Alex, étrave Thyssen-Waas, modèle de glace, M.V. Arctic.

Introduction

A new form of upward-acting icebreaking bow, referred to as the S-Bow because of its "snout bow" form and its "shearing" action (Figure 1), has been developed at Memorial University of Newfoundland over the period 1984–1986. Advances in arctic shipping have inspired progress in icebreaking technology, ice mechanics research, icebreaking analysis, remote sensing, and Arctic hydrography. The research program for the S-Bow has attempted to reflect this experience with a more sophisticated design philosophy.

The S-Bow concept draws upon two icebreaker bow types. Previous upward-acting bow designs have used a plow form, such as the Alex bow (Fig. 2a). The other influential design is the recent "landing craft" or "pontoon-type" bow, such as the Thyssen-Waas bow (Fig. 2b). This type of bow employs a shearing action to reduce ice resistance. Testing has proceeded over the past decade with considerable success (Molyneux, 1982; Freitas, 1980).

Description of the S-Bow

Figures 1a-1c illustrate the body plan, profile, and isometric view of the configuration selected for the S-Bow. While the concept originated as a combination of the Ice-Plow and the pontoon-type bow, the final configuration owes much to the 19th century "snout-bow" and the extreme-bulbous bow used in the late 1970's (Figure 3). The S-Bow consists of six elements, as labelled in Figure 1. The underside of the bow (labelled (1)) was not treated in this initial design phase which was based on level ice conditions. It would be a factor when treating other ice conditions such as pressure ridges. The forefoot (2 and 3) has a compound stem profile, with a narrow skeg along the centre line (2a) to ensure the formation of a centreline crack in the ice. The lower forefoot (2) is inclined aft near the centre line but becomes more vertical further aft toward maximum beam. The bow will submerge in an unbroken ice sheet, but should displace broken or pack ice sideways. The upper forebody (3) inclines back into the centreline to maintain a centreline crack and to ensure the flow of broken ice outward and aft. The shoulders (4) extend to maximum beam of the ship and resemble a truncated airfoil. The sharp edge formed at the shoulders acts to shear the ice at the vessel's sides, which produces a diagonal cantilever on each side of the centreline (Figure 4). Added buoyancy created by submergence breaks these cantilevers in flexure. The aft portion of the bow incorporates "tumble home" (5) and a flared forecastle (6) to clear the broken ice aft, down, and outward.

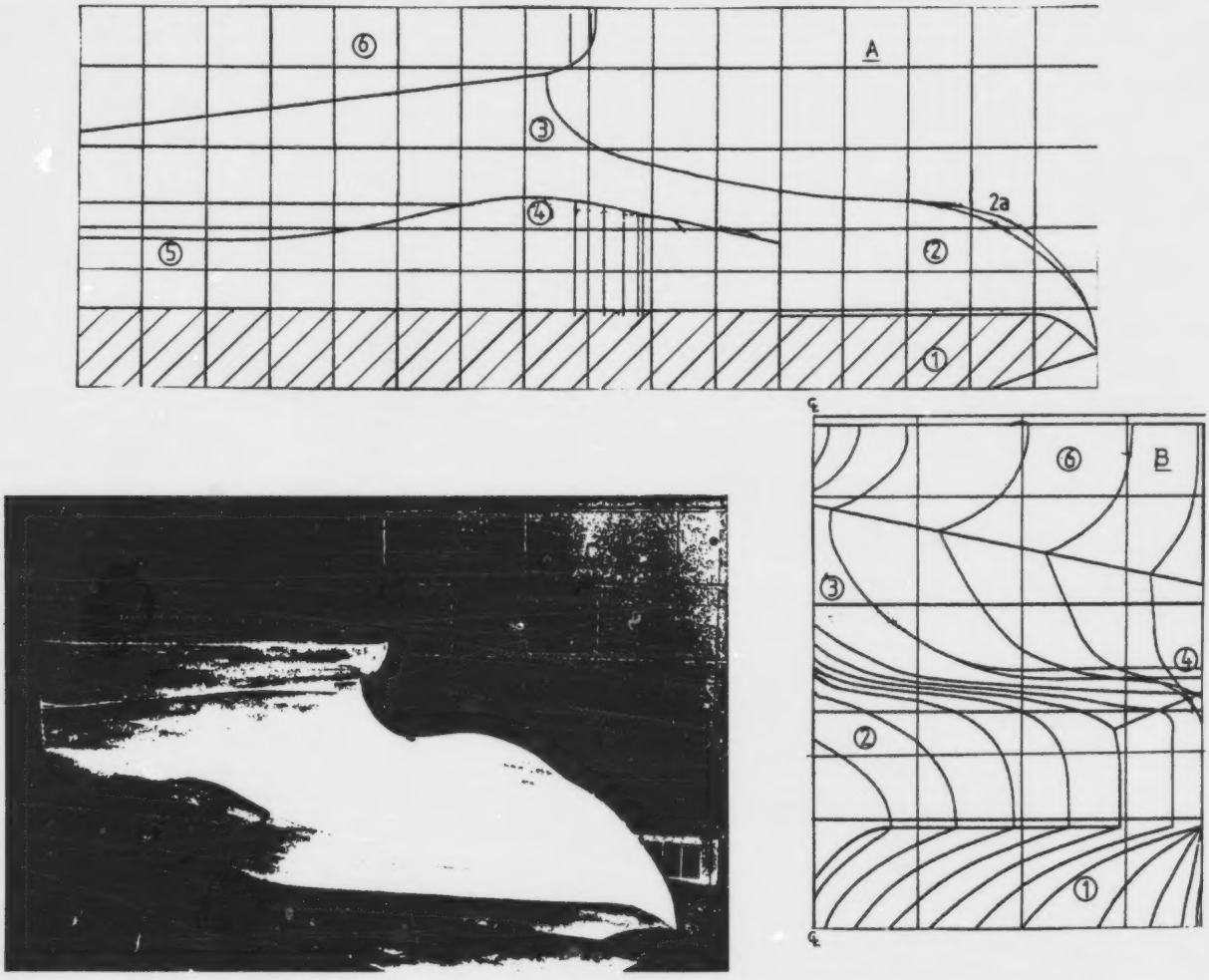


Figure 1. The S-Bow: a) Body plan b) Profile c) Isometric

Icebreaking design

Icebreaking design has evolved from a simple process of designing a hull and propulsion system capable of operating in ice to a systematic approach which incorporates: environmental factors, the operational profile of the vessel, ice mechanics, icebreaking technology, and the interaction of these components (German and Dadachanji, 1975). The classic ship resistance problem remains an important consideration, but within the context of the factors mentioned above.

In the design process a wide variety of conflicting concerns must be reconciled. Ice conditions are classified by age and physical description; each condition may favour a different form or technology. In addition, requirements for good open water performance generally conflict with efficient icebreaking design. Standard open-water design maxims, such as increasing size to improve economies of scale, may conflict with the hydrographic limits of the Arctic. Designing to minimixe ice resistance may reduce manouverability needed for hazard avoidance. Icebreaking can be considered a process consisting of ice fracture and broken ice management components; a design must balance the two components to be efficient. The Arctic, and other ice-covered regions, are areas which should foster technical innovation, but the high risks and reliability required of Arctic shipping discourages such innovation.

The final object of the design process is to produce a vessel which is neither under-designed or over-specialized. A number of sources are available for directing the design for an efficient vessel. Computerized route simulation, the vessel's operational profile, supported by a knowledge of ice mechanics and by numerical icebreaking analyses, provide guidelines regarding the vessel's size and form. Scale model tests provide physical observations and an estimate of propulsive power, prior to full scale tests. Much of icebreaking design is based on past experience, or on regulations based on that experience.

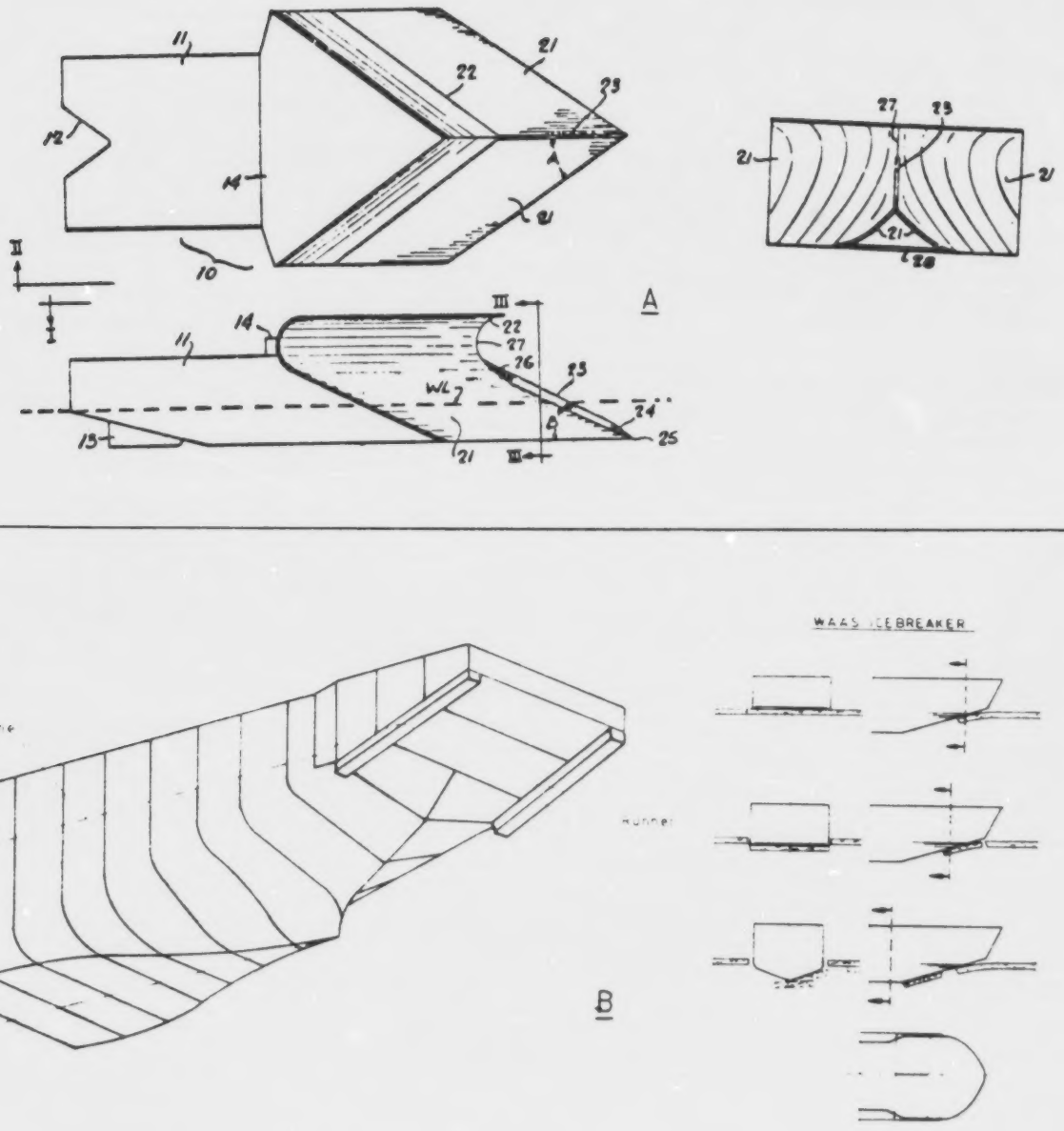


Figure 2. Influential designs: a) the Alex-Bow (from U.S. Patent)
b) the Thyssen-Waas bow (from Freitas, 1985)

An icebreaking vessel is the sum of many sub-systems, and therefore the optimization philosophy is very important. The performance of one component can be negated by the effects of another. Interaction of the bow form with the rest of the vessel has proved to be particularly important; bow-design should not be treated independently but as part of a "global system.

The upward-acting icebreaking bow concept

The upward-acting icebreaking bow concept is self-descriptive: the ice sheet is broken upward by the added buoyancy created as the bow is submerged. In contrast with conventional icebreaking designs, the broken ice is displaced alongside the vessel above the waterline. This action confers an upward-acting bow with certain "operational" advantages that are independent of the bow's ice resistance. These advantages are described below.

1) Application to semi-submersible hull forms

It has been recognized that a vessel's beam (width) is a significant factor in ice resistance. It should also be recognized that there are few suitable sites for deep-water harbours in

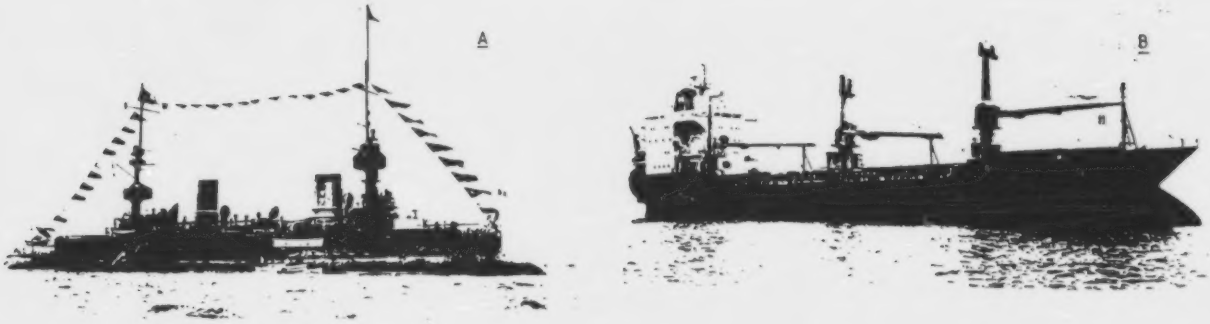


Figure 3. Influential forms: a) the *"Massena" circ.* 1898 (Jane's, 1905) b) Danish General Cargo Ship, 1977 (Motorship, 1977)

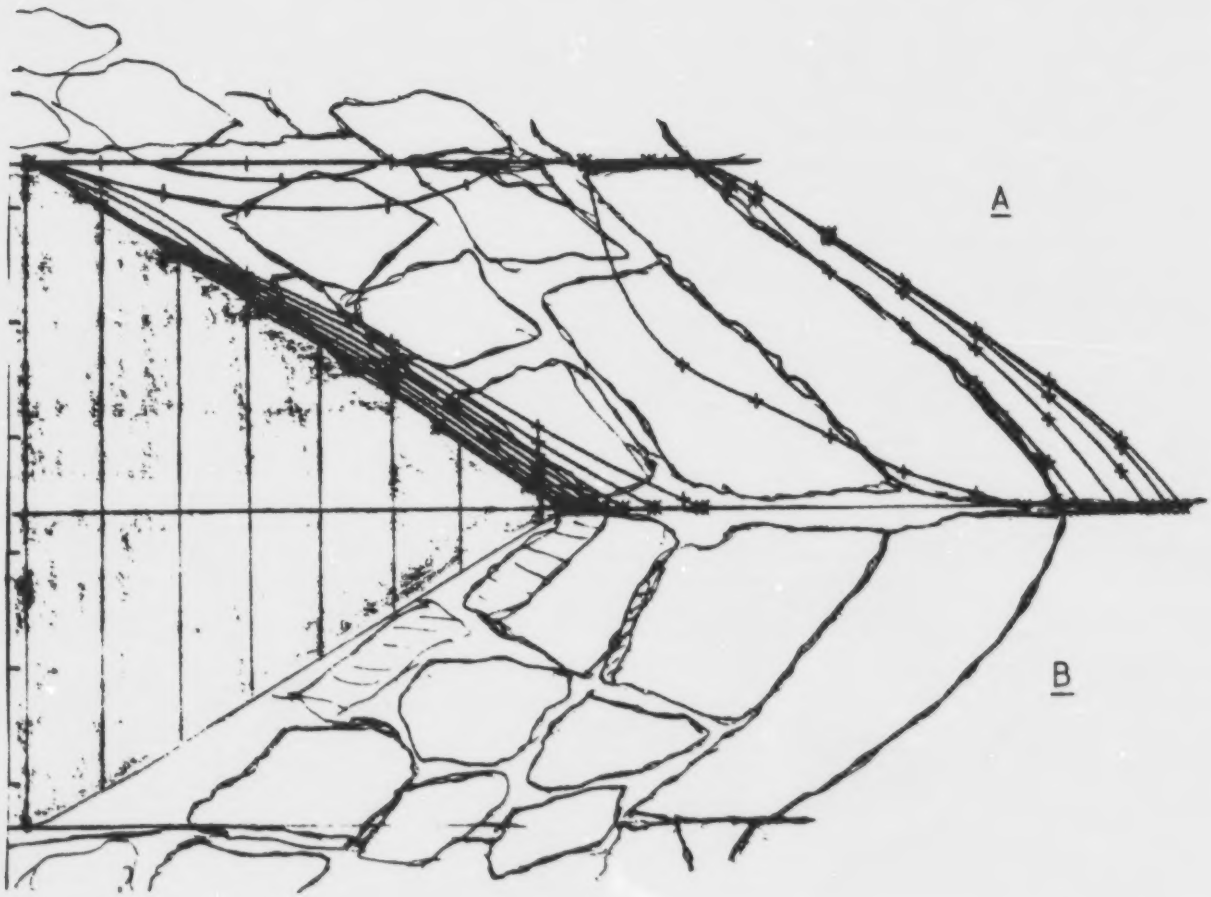


Figure 4. The breaking pattern of the S-Bow, as seen from above. Note the diagonal, crescent-like cantilevers, and the shearing cracks.

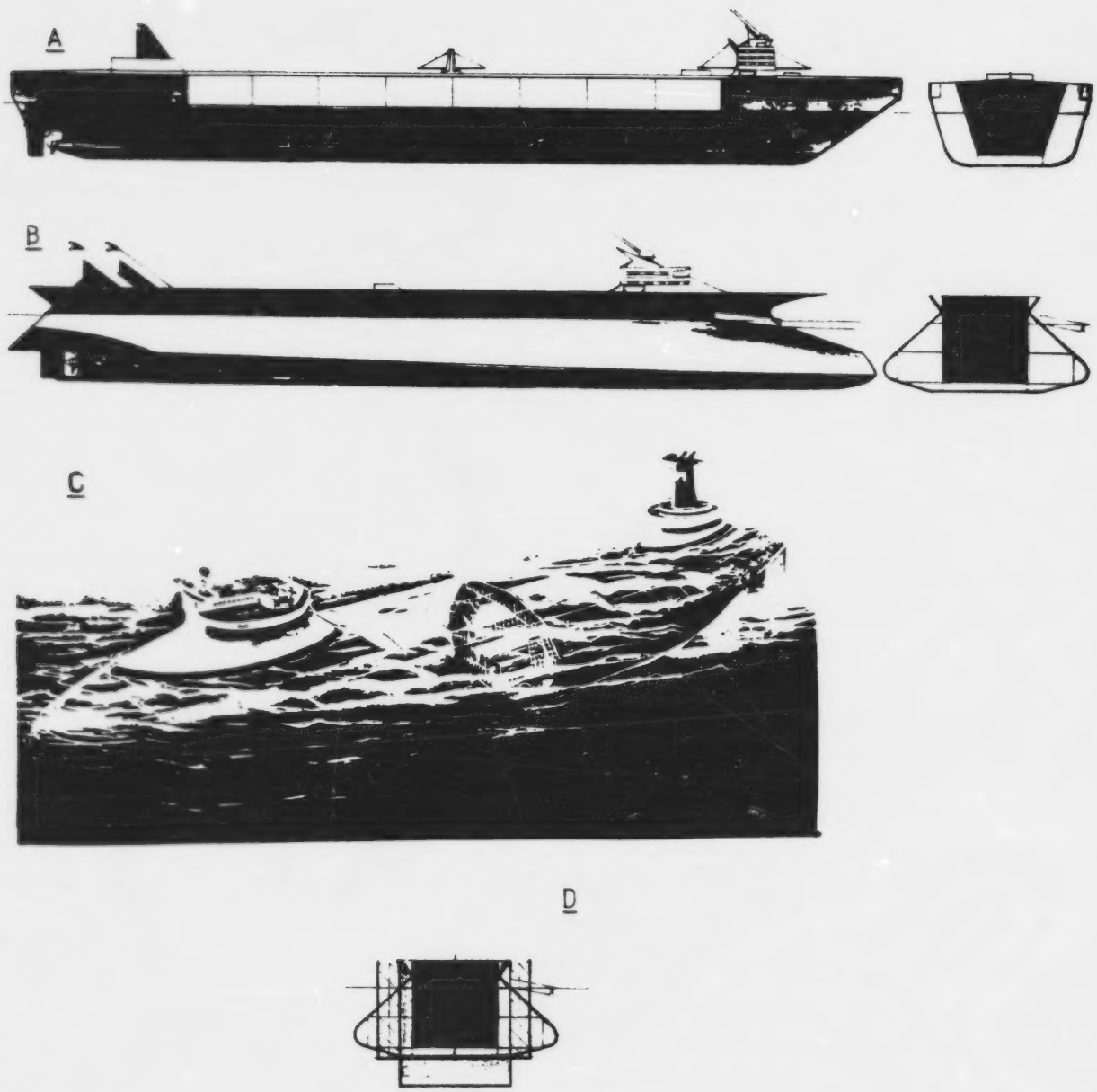


Figure 5. Alternative ice-class cargo vessel forms
a) conventional ice-class hull form
b) triangular-section semi-submersible form
c) sub-marine-like semi-submersible form
d) Section showing shallow draft of triangular form.
(from Ships and Shipping of Tomorrow [Trans.], 1978)

the Arctic. Efforts spent in optimizing a vessel design could be nullified by the need to construct an expensive, ice-classed mooring facility to service the vessel kilometres off shore. A conventional hull transverse section, usually rectangular, places limitations on beam and draft (depth) because the form is effectively defined (Fig. 5a). Semi-submersible hull forms featuring a narrow beam (Fig. 5) have been proposed; one type features a triangular section while the second type is more submarine-like. The triangular form is also a shallow draft form, as demonstrated in Figure 5d. These forms have certain structural advantages, but are specialized forms because their open-water performance is comparatively poor. The submarine-like form requires fixed ballast, and would be subject to draft limitations. Performance in deeper ice structures would have to be investigated. It is important to note that these forms were developed with an upward-breaking bow, and are far less suited to conventional icebreaking bow designs.

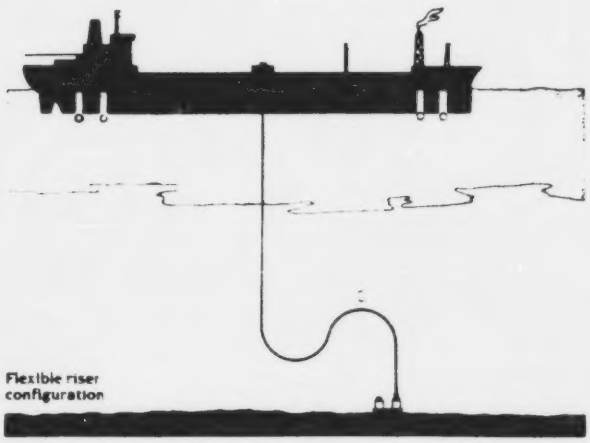


Figure 6. The single well oil production system [SWOPS] (from BP Shipping Brochure)

2) Maintenance of an ice-free "moonpool"

Offshore exploration has brought a number of specialized ships such as drillships, dredges, and diving support vessels, which operate using a "moonpool", an opening through the hull. These types of ships must operate in the short open water season in the Arctic. The "moonpool" can become clogged with ice and operations interfered with, even in specialized vessels such as the icebreaking drill barge "*Kulluk*", (Arctic News Record, 1985). These problems would be minimized with an upward-acting bow, with an attendant increase in productivity. As significant are the implications for floating production platforms that have been developed for "marginal" oil fields; the Single Well Oil Production System (SWOPS) is an example (Fig. 6). The ability of an upward-acting bow to maintain a "moonpool" could be important in adapting this technology to the Arctic. The requirement for an Arctic-class platform is in many ways a uniquely Canadian requirement.

3) Advantages of a fuller hull form

Because an upward-acting icebreaking bow extends underneath the ice sheet, the displaced volume of a vessel is effectively larger for a given length. A conventional icebreaker bow is cut away below the waterline. The added displaced volume of an upward-acting bow translates into added deadweight capacity. This is a feature of the inclined stem used on some Great Lakes' freighters (Fig. 7b). The volume in the bow itself may be used to house auxiliary icebreaking systems such as ballast tanks or air bubblers.

4) Reduction of ice interference with hull appendages

Ice impact with hull appendages, especially with the propellers or rudders, is a problem that reduces their efficiency, and at worst can cripple the vessel. The problem would not be entirely eliminated by an upward-acting bow because of deep ice structures, but the frequency of impact would certainly be reduced. In the Arctic, any improvement in operating efficiency and reliability is significant.

5) Elimination of snow friction

Snow cover can radically affect a conventional icebreaker bow; frictional resistance may quadruple (Enkvist, 1972). This is avoided by the action of an upward-acting bow, although the flow of the broken ice may be affected.

6) Production of an ice-free channel

The origin of much of the interest in upward-acting icebreakers was in the possibility of producing a clear channel for other shipping. Unfortunately the prospects are limited, as the broken ice tends to slide back into the channel aft of the vessel. Ice pressure, when present, would also close up the channel.

These "operational" advantages are related to design rather than performance. They would not be demonstrated in a simple comparison of the resistance of bow designs. Ice resistance is important, in that it is a measure of efficiency. Nevertheless, some of the specialized applications rely on an upward-acting bow. A lower ice resistance means the bow can be economically applied over a wider range of vessels. The design problem can then be stated as: to develop an upward-acting bow form with ice resistance comparable to conventional designs, so as to efficiently exploit the operational advantages of the upward-acting concept.

A history of upward-acting icebreaking bow design

Inclined surfaces have long been used in icebreaking river obstacles and lighthouse piers. The first example of an upward-acting icebreaker was the Canadian (pre-1867) side-wheeler "*Chief Justice Robinson*" (Fig. 7a) which was equipped with a ram bow to extend its operating season on Lake Ontario. It was constructed in 1842 — twenty two years before the first European icebreaker — and operated for over a decade. More recently, beginning in 1977, a number of Canadian Great Lakes' freighters have been equipped with an inclined stem to assist in late-season operations (Fig. 7b).

During the last half of the nineteenth century, most major warships were designed with a ram, plough, or snout bow (Fig. 3a). They were not intended for ice breaking, although some disarmed battleships were used as emergency icebreakers by Germany in the 1920's.

The most widely tested form of upward-acting icebreaker bow is the "Ice Plow" — the name is self-descriptive. It has had a very chequered history. The Soviets tested a form

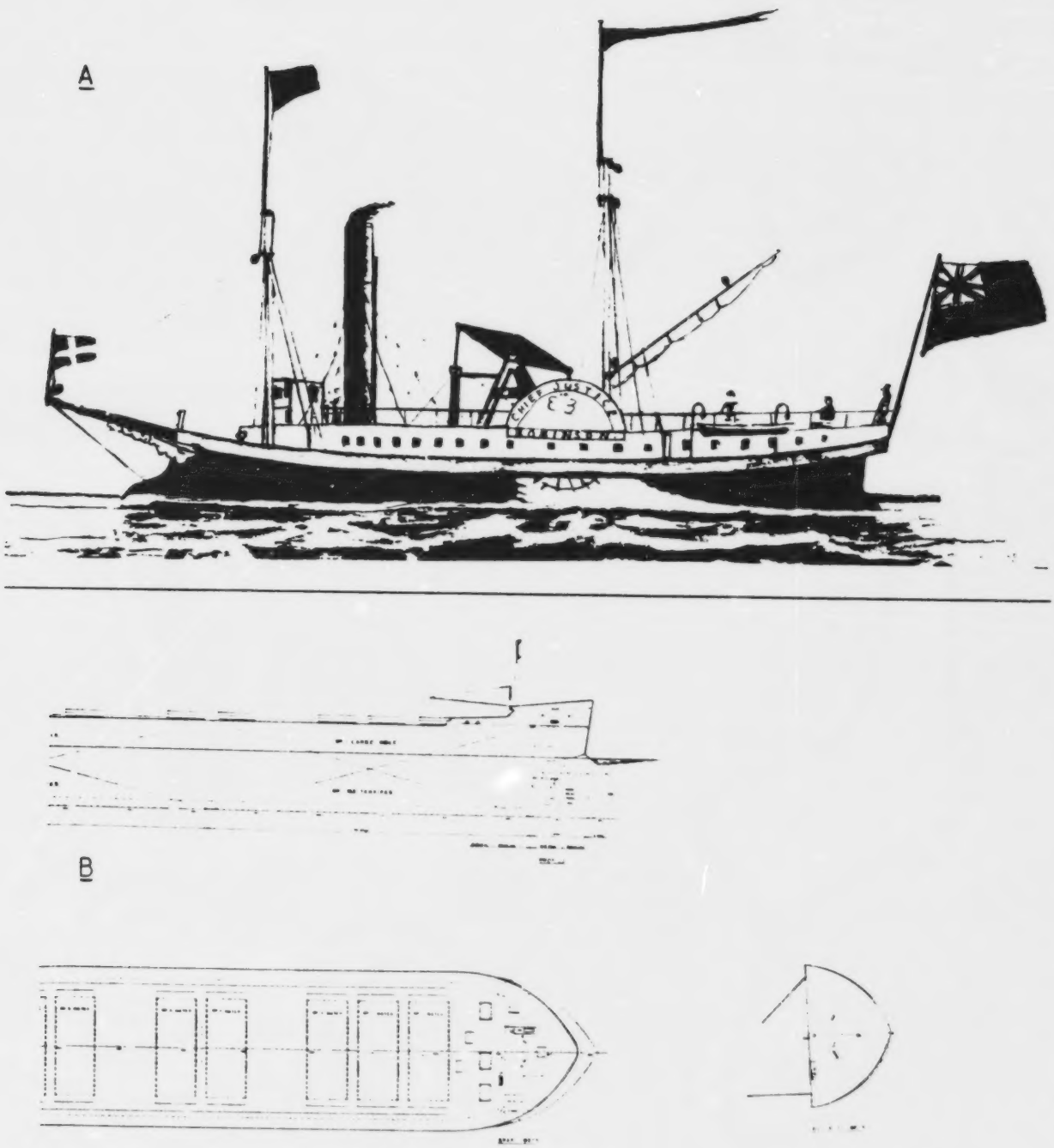
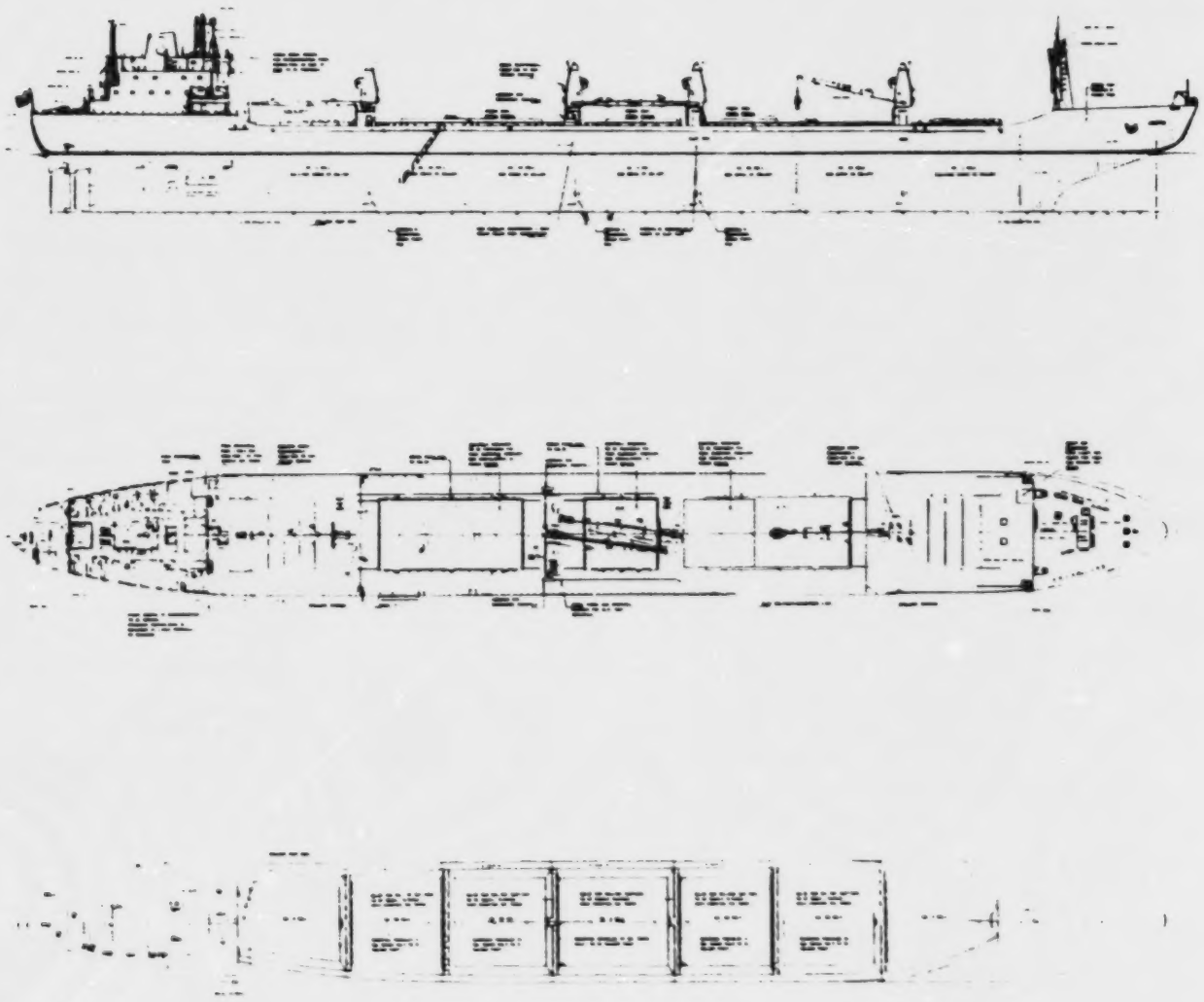


Figure 7. Upward acting icebreakers on the Great Lakes:
a) the "*Chief Justice Robinson*" *circ.* 1842 (from Barry 1973)
b) the bow of a freighter *circ.* 1985 (Canadian Shipping, 1985)



PRINCIPAL PARTICULARS Length overall — 220.8 m Length between perpendiculars — 206.16 m Breadth moulded — 22.86 m

Figure 8. Profile of the Class 4 OBO "*Arctic*" (Baker, 1985)

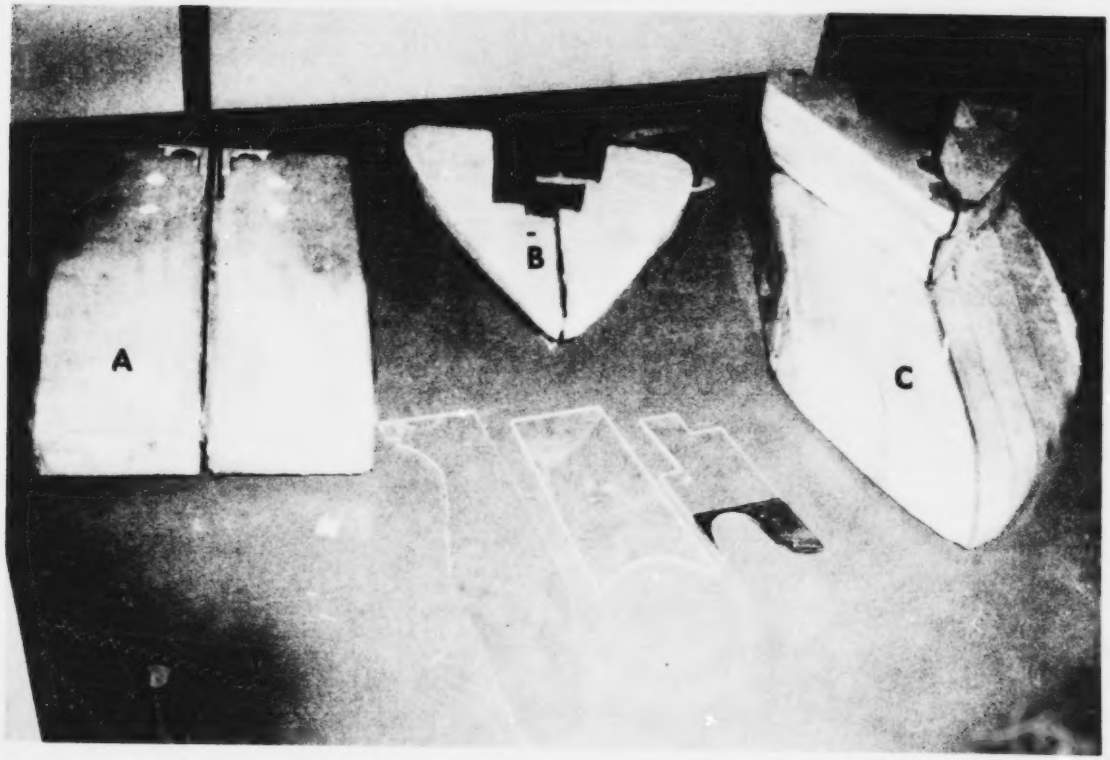


Figure 9. Alternative S-Bow configurations:
a) forefoot FF1 (showing 3 runners)
b) Overhanging forecastle FB1
c) forefoot FF2 with forecastle FB2

in the early 1950's as an attachment for river tugs. Trials indicated problems with ice clearing, such that the tug eventually jammed (Shvaistein, 1971). There were specific design problems, but similar tests in the U.S. in the 1970's were also unsuccessful. In the late 1960's an ice plow featuring a centre-line splitter (Fig. 2a) was proposed in Canada, designated the "Alex-bow". Early model and small scale tests were promising, and in 1968 a 2000 DWT. barge, the "*L.A. Learmonth*", was constructed for Panarctic Oils Ltd. for use in their summer Arctic re-supply operations. During this a modified "Alex-bow" was evaluated in large scale model tests of the oil tanker "*Manhattan*" (Gray, 1981). The bow was not adopted, and in July 1969 the "*Learmonth*" sank in an ice pressure field off Resolute, Cornwallis Island. Although a conventional barge was also lost, and the 6500 tonne icebreaker "*Labrador*" was beset in the ice, the bow received much (unofficial) criticism (Davies, 1969). Some design studies continued (German and Dadachanji, 1975; Kallipke, 1972) and an Eastern Canadian trawler was tested, but the incident effectively destroyed the interest in the upward-acting icebreaker for Arctic shipping.

Development of the S-Bow Concept

The S-Bow concept can be described as the combination of an ice-plow with the superior shearing action associated with a pontoon-type (Thyssen-Waas) bow. The advance over previous upward-acting bow designs is that crushing is minimized, which should reduce ice resistance. A sketch of the icebreaking pattern is shown in Figure 4. In developing alternative S-Bow configurations, a number of problems were addressed which provided direction to the design program:

1) The amount of trim required to provide the icebreaking buoyant force could result in inadequate propeller immersion. This problem is more related to the bow application, of matching ship to ice conditions, rather than to the bow design.

The ship selected for the bow evaluation program was the M.V. "*Arctic*", classed as an Arctic Class 4, Oil/Bulk Ore (OBO) Carrier of 38,000 tonnes displacement (Fig. 8). It is a long vessel with a high length: beam ratio (L/B=8.6); trim angles would be very small while having a low ice resistance. It was a good demonstration case for the S-Bow, with a large body of data available for reference.

2) The most basic configuration of the S-Bow used an inverted "pontoon" form (labelled FF1; Fig. 9a) which has a short, simple form, but its behaviour in pack ice, deep ice structures, and in open water would be questionable. A more streamlined forefoot (FF2 in Fig. 9c) resembling a "snout bow" was proposed. It had to be

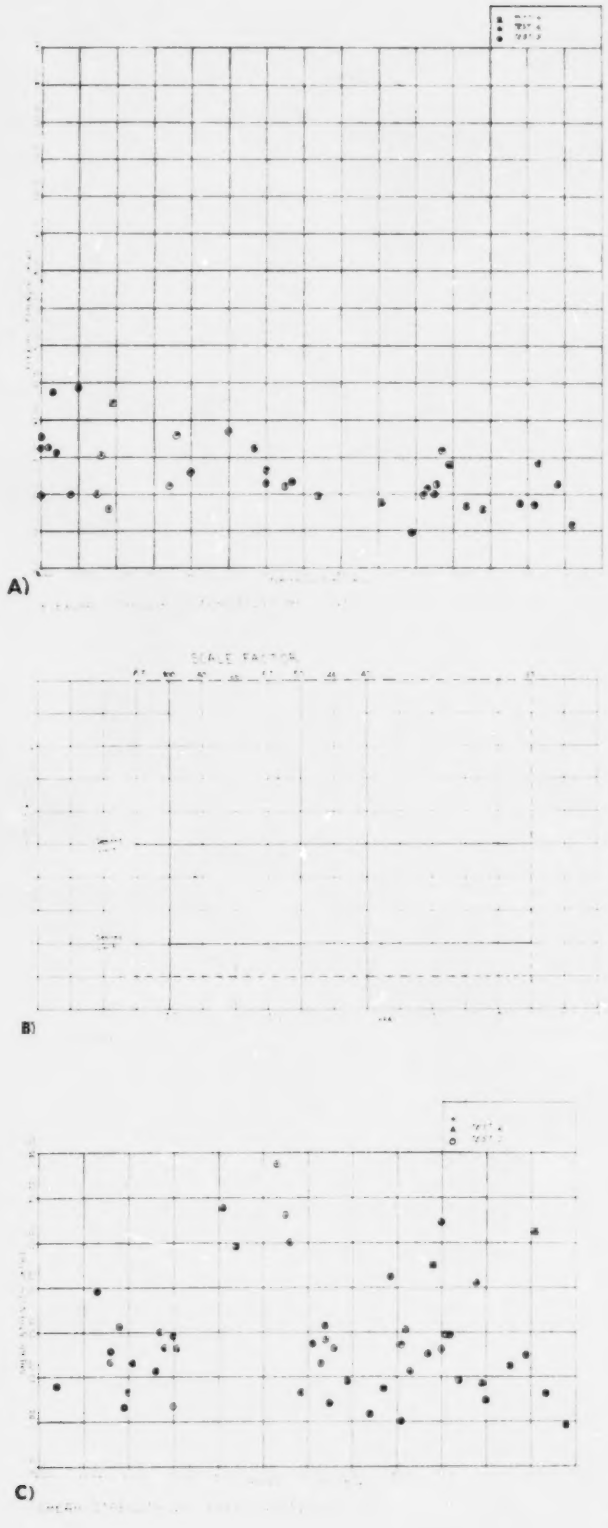


Figure 10. Ice sheet data:
a) Tempered strength
b) Modulus ratio vs flexural strength
c) Tempered shear strength

determined how the snout form affected the proposed breaking action.

3) The length of the S-Bow had to be comparable to a conventional ice-breaking bow. This placed limits on the waterline angles of the snout-type forefoot (FF2).

4) For an inverted-pontoon forefoot (FF1), the bow height had to be about half the beam, to keep ice from rolling on deck before it was fractured and displaced to the sides. The centre-line crack produced by the snout-forefoot (FF2) ahead of the shoulders meant that the bow height could be reduced.

5) The relative importance of ice fracture and broken ice management resulted in a number of alternative configurations for the shoulders, some of which featured skegs (runners). They are described in Table 1 below. Much of the experimental program was directed at this problem.

TABLE 1
Details of alternative S-Bow designs

Designation	Forefoot	Forecastle	Comments
FF1A	Inverted-Pontoon with two side runners	N/A	FF1-FF2
FF1B	Inverted-Pontoon with three equal sized runners	N/A	Forefoot evaluation
FF1C	Inverted-Pontoon, three runners, CL runner raised	N/A	(FFx)
FF2	A long Snout-type forefoot, tunnel shoulders with runners	N/A	
SS1	FF2	Stem Profile Only	Plow Type
SS2	FF2		Spoon Profile Overhanging
SS3	FF2		Plow with Overhang
FB1	FF2	Extreme Overhang Spoon Profile	Completed Forebody
FB1R	FF2 with runners reduced	"	Tests (FBx)
FB2	FF2 with no runners	Narrow Platform	
FB3	Short Snout form, tumble-home on sides, tunnel shoulders and runners	Wide Platform Blunt Stem	Developed as tests proceeded
FB3M	"	Ram-Plow, as FB3 extended, sharp, stem	
FB4	As FB3M, but with runners removed	"	
FB5	Snout forefoot with tumble-home, truncated air foil shoulders		

6) The upper forebody, which included the stem profile and flared forecastle, had to provide adequate flow of broken ice aft and outward from the bow in combination with the bow shoulders. Most forms were based on variation of the plow form; refer to Table 1 for details.

The evaluation program

The objective of the evaluation program was to demonstrate the feasibility of the S-Bow concept, and to select the best

configuration for use in large scale comparative resistance tests in level ice, again using the M.V. "*Arctic*" as a test case. This is the first stage in a long evaluation process. It was decided to attempt a small scale experimental program, which was only possible because recent types of model ice allowed for greater strength reduction (Timco, 1978; 1985). Computational methods lacked the flexibility and accuracy to analyze a new concept.

The tests took place in a refrigerated "cold" room located in the Memorial University Engineering building. The basin was an insulated aluminum tank, 1 m × 0.6 m × 0.45 m deep, which meant it was probably the world's smallest ice tank. The dimensions limited the scale to about 1:100 for the M.V. "*Arctic*". The ice was doped with a mix of 2.0% urea (carbamide), 0.05% detergent, and 0.03% sugar. Growth was initiated by "seeding" (spraying) with fresh water, which produced an ice sheet with a relatively thick polycrystalline upper zone, with columnar growth below. A growing time of 1.5 hours at −24°C produced an ice sheet 1.3–1.7 cm thick. The cold room was mechanically ventilated and had no humidity control. After 1.5 hours warming at −2°C, the following range of ice properties was obtained:

Flexural Strength	:	σ_f=8–30 kPa; 17 kPa average	) See
Modulus Ratio:		E/σ_f=800–5000	) Fig.
Shear Strength:		τ=9.5–27 kPa; 21 kPa average	) 10
Scale	:	λ=50–100	

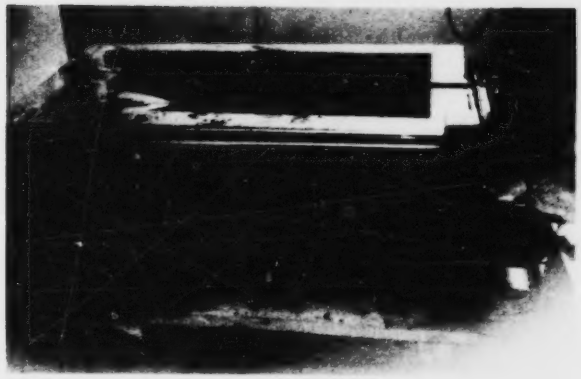
A flexural test was performed prior to each towing trial.

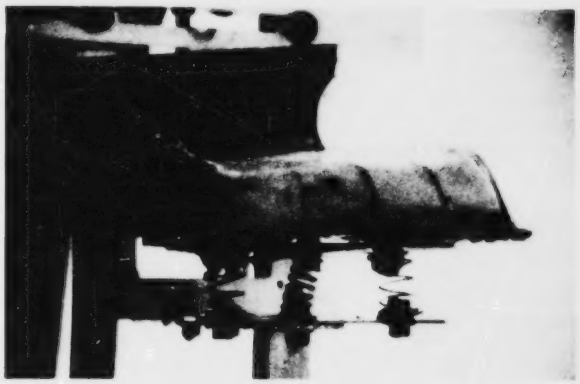
The model towing carriage consisted of a monorail system where a pivoted arm was towed at two points by cables drawn by a vee-belt and pulley system. Power came from a 0.4 kW, variable speed, DC electric motor. The system could provide the equivalent of a 0.3–3.5 knot speed range (Froude scale). Refer to Figure 11 for a view of the system. Instrumentation consisted of a cam-switch system counting revolutions of the drive shaft, which were recorded on an X-Y Plotter. The time scale of the chart was then used to estimate model speed. All trials were videotaped which provided the primary method for observation.

The models consisted of a bow segment mounted on a frame using compressive springs sized to simulate the restoring buoyancy of the hull (Fig. 11b). The equations of motion for heave and pitch for the M.V. "*Arctic*" were analyzed with the assistance of a seakeeping program (Meyers *et al.*, 1975). An analogue of icebreaking motion was used as an input wave, and the results were modified to account for strength. The mounting was able to be simplified to the displacement component of pitch. The bow models were constructed of styrofoam, reinforced with plexiglass, and an epoxy coating. As shown by Table 1, the designs were tested as three components: forefoot, stem profile, and complete forebody. All were tested at three speeds, corresponding to one, two, and three knots. At least two tests were recorded at each speed.

Summary of evaluation tests

A total of 119 trials were performed, of which 71% were successful, with 51% rated as good to excellent. Problems included: cable failures, humidity problems, temperature control problems, ice flooding, and inconsistent ice seeding.





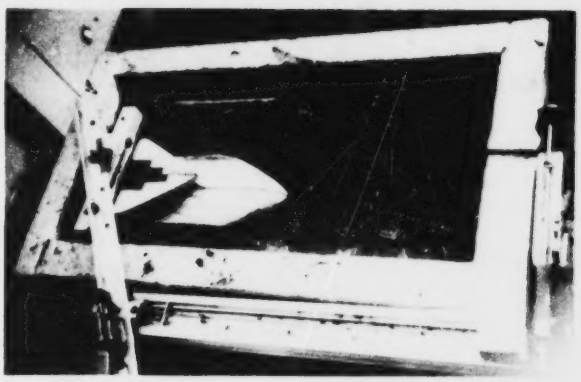


Figure 11. Small ice tank:
a) View of tank showing towing system
b) Model mounting system
c) Model in towing position

About 22% of the tests were performed with a pattern of holes drilled in the ice to better represent scaled ice piece size. Some insight into broken ice behaviour was obtained, but the ice tended to flood which nullified any improved cracking. These problems did not prevent useful observations; the tests were probably conservative due to the ice thickness and poorly-scaled fracture toughness, which produced larger ice pieces.

The initial stage of tests evaluated forefoot design. The inverted pontoon bow (FF1A) demonstrated that the bow shearing action could be modelled. Experiments with a third centre-line runner (FF1B and FF1C) indicated it had to be highly raised to be as effective as at the sides. The importance of the bow's wall sides was indicated. Tests with the snout-type forefoot (FF2) followed. Shearing of the sides and centreline were clearly visible, and therefore the snout forefoot was selected for further tests, because of the design advantages described previously.

The next stage evaluated stem-splitter profiles, using thin plexiglass sheets. The selection of the snout-type forefoot made these tests redundant, and they could have been deleted. At this stage some tests were performed in drill ice, and were also used in the next stage, which involved the completed forebody.

The first version employed a forecastle with extreme overhand (FB1). This type was unsuccessful, as broken ice tended to jam under the forecastle, even when the side runners were reduced (FB1R). The next version featured a narrow plow-type forecastle. A number of successful trials were run, but there were occasions when ice rubble stayed on the snout. This seemed to be a result of the forefoot length and the flat shape. A new form was developed (FB3) that better integrated the forefoot and forecastle which resulted in a shorter bow with more vertical surface, extending down to the waterline.

Tests with the new bow indicated that crushing occurred at the stem-splitter, and sharper stem was introduced (FB3M). It became clear that, in the absence of water flow, gravity was important in ensuring adequate broken ice clearing; the ice clearing component needed to receive greater emphasis. Tests were performed successfully on a version with the runners removed (FB4). The final version (FB5) replaced the "tunnel-form" shoulders with a truncated air foil, which did not impede the flow of broken or weaker ice while maintaining the shearing action. This version, FB5, was selected as the S-Bow configuration for use in large scale (1:30) comparative level ice resistance tests with the M.V. "*Arctic*" equipped with a conventional ("Melville") bow.

Conclusions

The conclusion of the configuration evaluation trials marked the transition between the conceptual development and the performance evaluation of the S-Bow. The feasibility of the S-Bow concept was demonstrated and the form was refined according to preliminary criteria. The next stage of development is to quantitatively evaluate the performance of the S-Bow in a variety of ice conditions and in open water. The final evaluation will then depend on weighing any performance penalty associated with employing the S-Bow against the merits of the upward-breaking bow concept.

Comparative level ice resistance tests against a conventional ice-breaking bow using a 1:30 scale model of the M.V. "*Arctic*" are scheduled for early December, 1986 at the Institute for Marine Dynamics, St. John's, Newfoundland.

Acknowledgments

The author would like to thank his supervisor, Dr. D.B. Muggeridge, Chairman of the Ocean Engineering Research Group at Memorial University, for his support and direction; Dr. S.J. Jones, Head of the Ice Group, National Research Council, Institute for Marine Dynamics, for his advice; and the Memorial University technical staff for their assistance during the experiment. The initial commissioning of the ice tank was done with the assistance of a fellow graduate student, W.H. Lau, and a work-term student, S.G. Decker. Financial support for this work has come from the Natural Sciences and Engineering Research Council (NSERC), Grant No. A4885, while the author has been supported on a Fellowship from the Centre for Cold Ocean Resources Engineering (C-CORE).

References

Alexander, S.E. 1970. Nautical ice-breaking structures. United States Patent Office. Patent No. 35231591. 3 p.

Baker, D.N. and Thompson, E.W. 1985/86. M.V. Arctic, design and conversion to Arctic Class 4 OBO. Marine Engineering Digest. Ottawa: Canadian Institute of Marine Engineers. 8–15.

_____ . 1985. Redesign of the M.V 'Arctic' Bow — additional model tests at HSVA and WARC. TDC Report No. TP5812E. Montreal: Transport Development Centre. 70 p.

Barry, J.P. 1973. Ships of the Great Lakes. Berkeley: Howell-North Books. 60–61.

Davies, J.F. 1969. Summary report of investigation into the circumstances surrounding the loss of the pump steel barges "L.A. Learmonth" and "Johnny Norberg" *etc.*, Report No. CA1 DTB12869A14, Dept. of Transport, 11 p.

Enkvist, E. 1972. On the resistance encountered by ships operating in the continuous mode of ice breaking. The Swedish Academy of Engineering Sciences in Finland. Helsinki. Report No. 24.

Freitas, A. and Nishzaki, R.S. 1985. Model test of an ice class bulk carrier with the Thyssen/Waas Bow Form. Proceedings of the 4th. International Symposium on Offshore Mechanics and Arctic Engineering. Vol. 2. Dallas. New York: American Society of Mechanical Engineers. 330–335.

_____ . and Wilckens, H. 1980. A novel icebreaker concept. InterMartec '80. Hamburg. 484–494.

German, J.G. and Dadachanji, N. 1975. Hull forms for Arctic bulk cargo transportation. SNAME Spring Meeting — New Horizons in Bulk Transport Systems. Vancouver. New York: Society of Naval Architects and Marine Engineers. 60–69.

Glen, I.F. 1984. The Canadian Arctic Marine Technology Program: A review. Marine Technology. Vol. 1, No. 3. New York: Society of Naval Architects and Marine Engineers. 242–255.

Gray, W.O. and Maybourn, R. 1981. Manhattan's arctic venture — a semi-technical history. Spring Meeting/STAR Symposium on Icebreaking Technology. Ottawa. New York: Society of Naval Architects and Marine Engineers. 1–19.

Kallipke, F. 1972. Polare Eisfahrt nit Frachtern. (Marine Transport with Commercial Ice Vessels in Arctic Regions). Schiff and Hafen. No. 10. Hamburg (In German) (Translation No. PB219200, National Technical Information Service. 16 p.)

Kloppenburg, M. and Schwartz, J. 1975. Neue Wege in der Eisbrechtechnik (New Ways in Icebreaking Techniques) Jahrbuch. Schiffbauttechnishe Gesellschaft Stg. V. 69 (In German). 197–212.

Lainey, L. and Tinawi, R. 1984. The mechanical properties of sea ice — a compilation of available data. Canadian Journal of Civil Engineering. Vol. 11. Ottawa: National Research Council of Canada. 884–923.

Legerer, F.J. 1975. Discussion contribution regarding improvement potential of ice-navigation. Arctic Systems Conference. St. John's. NATO Scientific Affairs Division. New York: Plenum Press.

MacDonald, E.A. 1969. Polar Operations. Annapolis: United States Naval Institute Press. 239 p.

Mathews, S.J. 1975. Aspects of the propulsive power of Arctic vessels, considering their operating environment. Spring Meeting/STAR Symposium on Icebreaking Technology. Montreal. New York: Society of Naval Architects and Marine Engineers.

Meyers, W.G., Sheridan, D.J., and Salveson, N. 1975. Manual — NSDRC Ship-Motion Sea-Load Computer Program. Bethesda: Naval Ship Research and Development Center, 129 p.

Milano, V.R. 1980. A re-analysis of ship resistance when in continuous motion through solid ice. InterMartec '80. Hamburg. 456–476.

_____ . 1975. Variation of ship/ice parameters on ship resistance to continuous motion in ice. Spring Meeting/STAR Symposium on Icebreaking Technology. Montreal. New York: Society of Naval Architects and Marine Engineers.

_____ . 1975. Ship resistance to continuous motion in mush ice. Spring Meeting/STAR Symposium on Icebreaking Technology. Montreal. New York: Society of Naval Architects and Marine Engineers.

Molyneux, W.D. 1983. M.V. "Arctic" and Two Alternative Bow Designs-Results of Resistance, Propulsion, and Overload Experiments, NRC Report No. LTR-SH-346, Arctic Vessel and Marine Research Institute, Ottawa: National Research Council of Canada. (Limited)

_____ . 1982. Field trials of the "Max Waldeck". NRC Report No. MTB-122. Arctic Vessel and Marine Research Institute. Ottawa: National Research Council of Canada. (Internal Report)

Noble, P.G. 1983. Arctic offshore technology — an overview. Marine Technology Vol. 20. No. 4. New York: Society of Naval Architects and Marine Engineers. 323-331.

Poznyak, I.I. and IONOV, B.P. 1981. The division of ice resistance into components. Spring Meeting/STAR Symposium on Icebreaking Technology. Ottawa. New York: Society of Naval Architects and Marine Engineers. 249-252.

Schonecht, R., Lusch, J., Schelzel, M. and Obenaus, H. 1978. Schiffe und Schiffahrt von morgen. (Ships and Shipping of Tomorrow). Rostock. (In German) (Translation Kahler, R.C. 1983). Cornell Maritime Press, Centreville, MD.) p. 112, 141-145.

Shvaishtein, Z.I. 1971. Ice-breakers for making ice-free channels. Leningrad. Problemy Arktiki i Antarkti (Problems of the Arctic and Antarctic). Vol. 38. 133-136 (English Translation available, 4 p.)

Timco, G.W. 1985. EG/AD/S: A new type of model ice for refrigerated towing tanks. Pre-print manuscript for October 1985. For: Cold Regions Science and Technology. Amsterdam: Elsevier Publishing.

_____ . 1980. The mechanical properties of saline-doped and carbamide (urea)-doped model ice. Cold Regions Science and Technology. Vol. 3. Amsterdam: Elsevier Publishing. 45-56.

Wade, N. (Editor). Fighting ice to extend Beaufort season. Arctic News Record. VOL 3.3. Bergen: Arctic News-Record Scanews. p. 7.

PHYTOGEOGRAPHICAL STUDIES IN THE KLUANE LAKE REGION, SOUTHWESTERN YUKON TERRITORY

Alain P. Roy

Department of Geography, University of Ottawa, Ottawa, Ontario K1N 6N5

Level: Master's

Abstract

As part of a long term study of the phytogeography and landscape ecology of the Kluane Lake area, two consecutive summers were spent studying alpine tundra vegetation in two distinct mountain ranges. Slope aspect, snowcover, soil depth, soil moisture and altitude are the main factors distinguishing the niches occupied by the various floristic units identified in the north-central Ruby Range.

Subsequent sampling in other parts of the Ruby Range and the Kluane Range pointed at the possibly highly chorological nature of the vegetation pattern. While numerous environmental differences can explain the local floristic dissimilarities observed, many vegetation units from well segregated areas are strikingly homologous in structure. No simple and direct relation has yet been found that can readily explain the spatial disparities in the regional alpine flora.

One case in point is the genus *Dryas*. The distribution pattern of its alpine species suggests no direct link with surficial geology or any other measured parameter. This reflects the evolution which has taken place in the landscape since dispersal patterns and initial site conditions resulted in the establishment or the dominance of a given *Dryas* species over other ones, at the time of colonization or later through competition and resource partitioning.

Key words: Landscape ecology, vegetation, alpine tundra, S-W Yukon, phytogeography.

Résumé

Dans le cadre d'une étude à long terme portant sur la phytogéographie et l'écologie du paysage de la région du lac Kluane, l'auteur a consacré deux étés successifs à étudier la végétation de la toundra alpine de deux chaînes de montagnes distinctes. L'orientation des pentes, la couverture nivale, la profondeur du sol, son humidité et l'altitude apparaissent comme les principaux facteurs distinguant les niches occupées par les diverses associations floristiques identifiées dans le centre-nord de la chaîne Ruby.

L'échantillonnage ultérieur dans d'autres secteurs de la chaîne Ruby et dans la chaîne Kluane semble indiquer la nature largement chorologique du patron de la végétation. Bien que de nombreuses différences environnementales puissent expliquer les dissemblances locales observées, on remarque que, dans plusieurs cas, des unités floristiques géographiquement bien séparées sont étonnamment homologues sur le plan structural. Jusqu'ici, aucune relation simple et directe expliquant les disparités spatiales dans la flore alpine régionale n'a été trouvée.

Le genre *Dryas* offre un exemple du problème. La répartition de ses espèces alpines ne suggère pas de lien direct avec la géologie de surface, ni avec aucun autre des facteurs mesurés. C'est là l'expression de l'évolution qui s'est produite dans le paysage depuis que, selon le site, établissement exclusif ou dominance d'une espèce particulière de *Dryas* résultait des patrons de dispersion et des conditions initiales du milieu, lors de la colonisation ou plus tard, suite à des effets de compétition ou de compartimentage des ressources.

Mots-clés: Écologie des milieux, végétation, toundra alpine, Sud-Ouest du Yukon, géographie botanique.

Introduction

Raup (1953) identified certain botanical problems of arctic and subarctic regions which are still of interest today. Not only did he mention the need to describe and analyze the plant communities of these regions, but also the need to study existing relationships between the spatial distribution of species and communities on the one hand and the geomorphological evolution of the landscape on the other. A relatively recent discipline, landscape ecology provides the geographer with a new approach to the study of vegetal organization in space. Landscape ecology focuses on spatial patterns, the

Figure 1. Study Area and Location of Main Sampling Sites.

The contour lines indicate the 5000' level.

interactions between the recognizable units of the patterns and the evolution of the landscape mosaic through time (Forman and Godron 1986).

The study area is located in the Kluane Lake region of southwestern Yukon, and comprises the Ruby and Kluane Mountain Ranges (Fig. 1). The Ruby and Kluane Ranges are separated by the Shakwak Trench and are also distinct geologically. The Ruby Range is mainly formed by a batholith of granodiorite although metamorphic rocks of the Yukon Complex are present to the southeast and northwest. The geology of the Kluane Ranges is more complex and comprises all the main types of rocks, from sedimentary to igneous. In both ranges alpine tundra is generally located at elevations varying between 1600m and 2300m.

Relatively few studies have been undertaken in the Kluane and Ruby Ranges concerning the spatial distribution of alpine vegetation. Botanical collections have been made (Porsild 1966, Hulten 1968) but no regional study of alpine vegetation has been attempted. In the Ruby Range, Price (1971) has studied the vegetation of a localized area and looked at the influence of exposure, depth of active layer and microtopography on the vegetation. In the Kluane Ranges, the vegetation ecology of Sheep Mountain was studied by Hoefs *et al.* (1975). Grier and Ballard (1981) conducted an ecological study in the mountains immediately to the south. As part of a palynological study, Birks (1977) studied the present vegetation of the eastern moraines of the Klutlan Glacier.

Objectives

The general objective of the project was the application of the principles of landscape ecology to the study of the tundra vegetation pattern in the alpine expanses surrounding Kluane Lake. This paper is a report on the first step of the work in which we examined two questions which are raised by the very use of the landscape unit concept:

What is the general floristic composition of the recognized landscape units?

Evidently, there is a certain repetition of the units in space to form the landscape mosaic. How accurately are the floristic units repeated in space and what are the main factors contributing to the repetition of a particular floristic unit in space?

First, we must identify and describe the main floristic units to produce a classification. Once a classification is established, it becomes possible to study the spatial relations between the environmental factors and the floristic composition. Both of these steps were undertaken after the first field season but had to be periodically revised as new data became available. After the first field season, special attention was given to the spatial distribution of the genus Dryas, as it appeared that there was a regional segregation pattern for the different species of that genus. The geography of the genus *Dryas* in the Kluane Lake area is the subject of an ongoing Master's thesis (Roy, A.P., 1987, in prep.).

Methods

The initial field vegetation survey was carried out during the summer of 1984 in the north-central Ruby Range (Fig. 1). In 1985, the southeast and northwest sectors of the Ruby Range were sampled as were several areas of the Kluane Ranges. The 1986 field season was spent solely on the study of the genus *Dryas*. The visibly different floristic units were sampled with the quadrat method. Ten quadrats, each one having an area of 1 m^2 were placed on alternate sides of a 20m long transect. Their respective position along the transect line was determined by a random draw. The distance between each quadrat and the transect line was also random and varied between 0 and 2m.

In each quadrat, a specimen of each species encountered was collected for identification and frequency count. The relative cover of the more important species was also estimated. At each site, topographical and edaphic parameters were measured: elevation m.a.s.l., relative elevation, meso- and micro-relief, slope angle and aspect, drainage, soil profile. A soil sample was taken at each site.

The identity of the plant specimens was verified in Ottawa. The data gathered were analyzed in three stages. The sites sampled were first classified into community types. Descriptive and diagnostic species were then determined for each community type. Lastly, the data were used to perform an indirect ordination in an attempt to identify the more important compositional gradients.

The classification program is based on an information theory algorithm (Dale and Anderson 1972) and was written by Dr. M. Phipps at the University of Ottawa, as were the other programs used in this study. It is an agglomerative hierarchical classification. The dendrogram can then be used at a chosen level of generalization to produce a number of groups of floristic units which are called community types.

In the search for ecological indicators, the species composition of each sampled site is examined and a list of descriptive and diagnostic species (by order of decreasing importance) is produced for each type of community. A descriptive species has a relatively high average frequency in a given type of community. A diagnostic species may also be a descriptive species but it is more restricted in distribution and therefore representative of a given community type when found in combination with certain other diagnostic species.

The indirect ordination technique of correspondence analysis extracts factors along axes which can be regarded as compositional gradients representing dimensions of variation in floristic composition. These compositional gradients can then be related to the variables measured in the field. The program is designed to produce an assigned number of factors. Experience has shown that the first four factors produced are usually the most meaningful ones. The first factor represents the compositional gradient which maximizes the difference or distance between the extremes of floristic composition. The second factor does the same but it is orthogonal to the first one, and so on. The four factors retained therefore express the distances between community types in four of the dimensions of the distributional hypervolume (Hutchinson 1957) in which the sampled floristic units are located.

Results

The classification of the plant communities surveyed during the first field season in the north-central Ruby Range resulted in the identification of ten community types (Table 1). The larger proportion of the sampled sites were grouped in four

TABLE 1
List of the 10 community types and general habitat description.

code	number of sites	habitat description
C01	2	low altitude, east slope (17 deg.)
C02	2	steep W slopes (33 deg.), small depressions
C03	5	N slopes (14–26 deg.), depressions
C04	13	dry summits below 2200m or dry upper slopes
C05	5	1700–2000m, W or SW slopes (10 deg.), deep soils
C06	5	1550–1700m, E or SE slopes (23 deg.), mesic sites
C07	1	1725m, SE slope (14 deg.)
C08	2	1850m, lower W slopes of small drainage asin (18 deg.)
C09	1	1850m, NW slope (12 deg.), wet
C10	1	2150m, upper altitudinal limit of tundra vegetation on peak 7255′

TABLE 2
Some descriptive species of the 10 community types.

community type	species name	av. frequency per quadrat
C01	Dryas octopetala	0.95
	Hierochloe alpina	0.95
	Senecio fuscatus	0.75
	Carex microchaeta	0.75
C02	Dryas octopetala	0.95
	Vaccinium uliginosum	0.95
	Pedicularis capitata	0.90
	Pyrola grandiflora	0.80
	Carex microchaeta	0.80
C03	Salix arctica	0.92
	Carex microchaeta	0.90
	Dryas octopetala	0.80
	Cassiope tetragona	0.76
C04	Carex microchaeta	0.89
	Dryas octopetala	0.83
	Oxytropis nigrescens	0.77
	Salix arctica	0.74
	Hierochloe alpina	0.64
C05	Carex microchaeta	0.94
	Polygonum viviparum	0.84
	Salix arctica	0.70
	Dryas octopetala	0.68
	Carex nardina	0.66
	Hierochloe alpina	0.64
C06	Dryas octopetala	1.00
	Festuca altaica	0.82
	Carex microchaeta	0.74
	Hierochloe alpina	0.66
C07	Dryas octopetala	1.00
	Hierochloe alpina	1.00
	Artemisia Tilesii	0.90
	Oxytropis nigrescens	0.80
	Campanula lasiocarpa	0.80
C08	Salix arctica	1.00
	Artemisia Tilesii	0.95
	Carex microchaeta	0.95
	Festuca altaica	0.95
	Anemone parviflora	0.80
	Stellaria longipes	0.70
	Aconitum delphinifolium	0.65
C09	Carex microchaeta	1.00
	Saxifraga Lyalii	1.00
	Salix arctica	0.90
	Senecio atropurpureus	0.60
C10	Saxifraga serpyllifolia	0.90
	Phlox sibirica	0.80
	Saxifraga oppositifolia	0.70

community types, namely C03, C04, C05 and C06. C04 is by far the most common community type. It represents floristic units located in dominating areas at or below 2200m, or on upper dry slopes. Soils are thin and meso-relief is varied but never pronounced. C05 is representative of west or south-west slopes of medium inclination (10 deg.) in deeper soils, such as those found on solifluction lobes. C06 regroups a class of communities all found on peak 7255′ (61 deg. 32′N, 138 deg. 22′ W). They are generally mesic sites with soils of medium depth. C03 is typical of areas with a good winter snowcover. The floristic units regrouped in this community type are located in sectors naturally suited for snow accumulation, either in depressions or in the lee of a prominence, at various elevations. Closely related are the units of a west slope which form C02. Lastly, C08 represents the tussock community occupying the lower slope of a drainage basin while C01 regroups sites at the lower limit of the alpine herbaceous tundra. The remaining types are isolated samples.

The program of search for ecological indicators produced, for each community type, a list of descriptive and diagnostic species (Tables 2 and 3). It is this list of descriptive and diagnostic species which determines the relative position of each floristic unit in the indirect ordination.

The first factor of the indirect ordination opposes the community types C10, C04 and C05 to C02 and C03. The order suggests that the factor represented here is the relative snow accumulation. Both C02 and C03 have conditions which favour snow accumulation and contain the species *Cassiope tetragona* which is well-known for its survival strategy using snowbanks (Savile 1972). On the other hand, C04, C05 and C10 are found in sites where little protection is provided by the physical environment and where plants rely on other strategies. *Phlox sibirica* and *Silene acaulis* are particularly well adapted to those conditions with their respectively low-matted and cushion growth forms.

The second compositional gradient reflects the different growth conditions and the associated biomass production. Communities with generally more favorable conditions for biomass production (C06, C08) are opposed to communities located in harsher environments where biomass production is more restricted. A diagnostic species of community types C06 and C08 is *Festuca altaica*, a caespitose graminoid. In harsher environments, *Phlox sibirica*, *Cassiope tetragona* and *Pyrola grandiflora* are diagnostic species. The compositional gradient, in this case, is a complex intermingling of various abiotic parameters: relative insolation (as measured by slope aspect), soil depth and moisture. These factors combine in various ways to produce a gradient where growth conditions are expressed by the strategy of biomass production used by the more characteristic plants of the community. *Cassiope tetragona* and *Phlox sibirica* both use an incremental strategy for growth whereas *Festuca altaica* makes use of the greater supply of nutrients and water to produce a seasonal tuft which dies back in winter.

A soil moisture gradient is suggested by the third axis. It opposes the units of C05 and C08 to those of C04, C06 and C07. At the more hydric extreme of the gradient we find the floristic units with better water retention because of relatively deep soils and hence adequate water supply throughout the period of growth: they are grouped in C05 and C08. The communities at the more xeric end of the gradient (C04, C06,

TABLE 3
Diagnostic species of the ten community types.

community type	diagnostic species (in decreasing order of information)
C01	Vaccinium uliginosum; Festuca altaica; Cladonia stellaris; Senecio fuscatus; Ledum palustre.
C02	Ledum palustre; Vaccinium vitis-idaea; Pyrola grandiflora; Cassiope tetragona; Vaccinium uliginosum; Campanula lasiocarpa; Senecio atropurpureus; Pedicularis capitata; Salix polaris.
C03	Saxifraga Lyallii; Pedicularis capitata; Pyrola grandiflora; Cassiope tetragona.
C04	Phlox sibirica; Draba stenopetala; Senecio fuscatus; Oxytropis nigrescens; Saxifraga flagellaris; Saxifraga nivalis.
C05	Gentiana algida; Llodyia serotina; Salix polaris.
C06	Minuartia biflora; Artemisia arctica; Calamagrostis purpurascens; Gentiana propinqua; Campanula lasiocarpa; Potentilla fruticosa; Festuca altaica; Pedicularis capitata; Androsace chamaejasme; Saxifraga nivali
C07	Campanula lasiocarpa; Festuca altaica; Cladonia stellaris.
C08	Gentiana algida; Aconitum delphinifolium; Anemone parviflora; Campanula lasiocarpa; Stellaria longipes; Festuca altaica; Lloydia serotina.
C09	Saxifraga Lyallii; Stellaria longipes; Senecio atropurpureus.
C10	Draba stenopetals; Saxifraga nivalis; Phlox sibirica.

C07) either have an early supply only or soils that drain too quickly because of slope or texture, or both. *Aconitum delphinifolium* and *Lloydia serotina* are diagnostic species of a more hydric environment whereas *Saxifraga nivalis* and *Campanula lasiocarpa* are typical of drier sites. Most mosses, especially the species of *Sphagnum* are also good indicators of wetter environments while most lichens and a few mosses (*Rhacomitrium lanuginosum, Polytrichum piliferum*) thrive in drier habitats.

The fourth axis suggests an altitudinal gradient with emphasis on the stage of soil formation. It generally opposes communities of either lower altitude or more developed soil profiles (or both) to communities of higher latitude or poorly developed soils. However, because most of the sampled sites are located in the intermediate altitudinal zone (1650m to 2000m) and some community types consist of one or two sites, more sampling is needed to better define the nature of this gradient.

Until specific soil analyses point to the contrary, it appears that the soils are generally of two types: cryosols and regosols. Within each soil order, soil type does not seem to be a strongly determining factor in vegetation distribution. The rock underlying the soils of the 1984 study area is mainly granodiorite, as reported by Muller (1967). The typical profile of well-drained sites consists of a humus layer topping an A-horizon, less than a meter thick, which extends down to the parent material with little differentiation but a progressive decline of organic content. In some areas (C05, C08), there is a certain accumulation of fines because of topography and geomorphological processes, resulting in a deeper soil profile. Only in the areas with poor drainage or with a prolonged summer water supply, because of the proximity of snowbanks, have soils which belong to the cryosolic order been found. The presence of a layer of volcanic ash at some sites does not appear to affect the vegetation cover significantly.

Since the analyses described above were performed, new data have been gathered, not only in other sectors of the Ruby Range but also in the Kluane Ranges. Although the complete analysis of all data now available remains to be done, some facts can already be presented. When the classification procedure is repeated for all the data from both the Kluane and Ruby Ranges, a clear dichotomy results: the samples from the first field season generally remain segregated from those of the second. Yet, the floristic units sampled in the Kluane Ranges and in the Ruby Range generally appear to be subject to the same interplay of environmental conditions. In particular, snow accumulation and soil depth stand out as determinant factors in most community types. The dichotomy is a regional one: the floristic units tend to differ between the ranges. Not only is this the result of diagnostic species being substituted locally but in some instances, also descriptive ones. While it is a relatively simple task to determine the preferred environment and hence explain the distribution pattern in the case of indicator species, it is quite another matter in the case of ubiquitous species with apparently largely erratic distribution patterns.

Dryas octopetala is one such species in the Kluane Lake area. In terms of primary productivity and cover, it is a remarkable species of the alpine tundra. It is found throughout the Ruby Range, regardless of geology which has been found to affect the distribution of so many other plants. There appear at this stage to be two ecotypes, *alaskensis* and *octopetala*, of wetter and drier environments respectively, much as described by McGraw and Antonovics (1983). This same species occupies much of the Kluane Ranges. Yet, in some parts of these ranges it is replaced by *D. integrifolia*. The causes of the substitution are not clear. There are several reasons for this. First, hybridization seems quite common and hence leads to a taxonomical problem. Also, at the present time, the geography of the genus *Dryas* is not well known. Lastly, distinct *Dryas* species other than those which have routinely been recorded in the past may also be present. *Dryas octopetala* has been found by the author in locales thought to be the exclusive domain of *D. integrifolia*, such as Sheep Mountain (Fig. 2). The two ecotypes of *Dryas octopetala* appear to occupy all of the Ruby Range, to the exclusion of *D. integrifolia*. Across the Shakwak Trench, in the Kluane Ranges, *D. octopetala* again occupies large tracts of the alpine tundra but here, some areas are the exclusive domain of *D. integrifolia* while other ones are occupied by both in varying proportions. At the present time, the distribution pattern of the alpine members of the genus *Dryas* suggests no direct link with surficial geology or any other measured environmental characteristic.

Discussion

The classification by hierarchical agglomeration of the central Ruby sample sites into community types generally appears to have provided a good picture of the plant mosaic of the subarctic alpine tundra for the study area. The ten community types identified in the first field season data do represent floristic associations which differ markedly in their structural and ecological characteristics. The indirect ordination has shown that the habitats occupied by the various community types described can be distinguished on the basis of snowcover, overall growth conditions (aspect, soil depth and moisture), soil water content throughout the summer and

Figure 2. Distribution of the genus Dryas in the Kluane Lake region.
The contour lines indicate the 5000′ level.

altitude, primarily as it affects soil formation. These parameters closely resemble those found to be important by Hoefs *et al.* (1975), although the vegetation of Sheep Mountain is often quite different since this site is in the Kluane Ranges. Snowcover is extremely important in determining the vegetation type, as is demonstrated by the fact that it relates to the first and maximum compositional gradient found.

One obvious weakness of these preliminary results is the low number of samples. But in this respect, the results can only improve as new sampling data are added. Another problem is the disparity in the frequency of community types. C04, for example, is very common, especially when compared to C07 or C08. In the future, rarer community types will have to be sought out carefully to ensure that they too are sampled adequately in each sector. In this respect, the curve of the relation between sampling effort and information gain for a given community type is a useful practical tool even though its use in attempting to predict a general relationship has not proven particularly fruitful.

With the extension of the sampling to the regional scale in an attempt to better define the landscape units, the importance of the spatial dimension in the floristic composition has been revealed. This factor had already been hinted at. C06 is a community type of the central Ruby Range formed by floristic units which often differ markedly with respect to their environmental characteristics. Yet their proximity must result in spatial interactions which are reflected in the floristic composition, in some form of partial overriding of the environmental controls which would otherwise better differentiate them: there must be some form of floristic contagion. Of course, some environmental conditions are similar for all the units regrouped in C06. Yet, just across the valley, floristic units with very comparable environmental characteristics are not included in the community type C06 because their floristic composition is significantly different. More sampling is needed to study the extent and importance of the chorological effect at the topographical scale, that of the meso-landscape.

The results of the latest classification are clear: there is a regional dichotomy. This grouping of samples by region is largely the result of secondary species which are characteristic of one region, either because of mere presence or frequency. The dominant species can be different as well, although this is less frequent. While numerous local environmental variations explain the different diagnostic species, the explanation is less obvious in the case of dominant species such as *Dryas octopetala* and *D. integrifolia*. The study of the regional pattern of the landscape may be somewhat hindered by the taxonomical species concept, at least when the functional structure of the units is concerned. In fact, if the community types of the two different regions are compared at a level of abstraction higher than the taxonomic species, homologous pairs are readily identified. Even when two floristically very different community types from distant but similar habitats are compared, a high degree of structural homology is commonly present. Brosseau (1986) has suggested that it may be useful to introduce a higher order of vegetation than the community. He tentatively suggested the name "meta-community". When studying the occupation of environmental niches by floristic units and especially the repetitivity of the landscape units in geographic space, it appears essential to use a level of abstraction better suited to the study of the regional structural homologies.

The explanation of the regional distribution pattern of *Dryas* cannot be based solely on the environmental factors cited in the analysis of the landscape mosaic of the north-central Ruby Mountains. Why for instance would *D. octopetala* occupy such geologically and climatically different areas as the northwestern, central and southeastern Ruby Mountains and large sectors of the Kluane Ranges and yet be replaced in parts of the latter where pH, water availability and other factors generally appear to be well within the range experienced elsewhere? This suggests that there is a chorological factor of critical importance. The observed pattern of distribution of the *Dryas* species reflects the evolution which has taken place in the landscape since dispersal patterns and initial site conditions resulted in the establishment or the dominance of a given *Dryas* species over other ones, at the time of colonization or later through competition and resource partitioning.

At the regional scale, with an ubiquitous genus such as *Dryas*, it may be feasible to identify the chorological mechanisms which have influenced or influence the present pattern of distribution. If no single environmental factor nor combination of factors can explain the pattern, then the explanation may partially lie in the pattern itself. While no obvious explanation has been found until now, many possible avenues have yet to be examined concerning the influence of the environmental factors and the spatial dimension on the floristic composition of a given landscape unit.

The phenotypic pattern is being studied and a classification of the phenotypes will be produced. This should shed some light on the nature of the genetic interactions between the two main types found in the region, *octopetala and integrifolia*. Only then will the study of the clines become feasible. It is in the study of those clines, we believe, that lies the explanation of the regional distribution pattern of the genus *Dryas*.

Conclusion

Landscape ecology, because it seeks to include the often forgotten dimension of space in the study of the relations between living things and the physical world, can provide new angles of approach to ecological questions. Geographers who study problems of landscape ecology must not be concerned with the mechanistic and reductionistic questions which are best left to more traditional forms of ecology such as autecology. Rather, they must seek an understanding of the spatial dynamics of the landscape, an endeavor which is truly geographical. The regional distribution of the tundra plant species and their association in landscape units are such problems. The study of the distribution pattern of the genus *Dryas* in the Kluane Lake area may contribute to a better understanding of the influence of space on the landscape mosaic by examining how space becomes a factor in floristic make-up at the different scales of the landscape.

References

Birks, H.J.B., 1977. Modern pollen rain and vegetation of the St. Elias Mountains, Yukon Territory. Can. J. Bot. 55:2367-2382.

Brosseau, M., 1986. Structure du paysage de la toundra alpine, région de Kluane, Yukon. Unpublished report to the R.C.G.S.

Dale, M.B. and Anderson, D.J., 1972. Qualitative and quantitative information analysis. J. Ecol., 60:639-654.
Forman, R.T.T., et Godron, M., 1986. Landscape Ecology. John Wiley & Sons, 619 p.
Grier, C.C., et Ballard, T.M., 1981. Biomass, nutrient distribution, and net production in alpine communities of the Kluane Mountains, Yukon Territory, Canada. Can. J. Bot. 59:2635-2649.
Hoefs, M., McT. Cowan, I., et Krajina, V.J., 1975. Phytosociological analysis and synthesis of Sheep Mountain, southwest Yukon Territory, Canada. Syesis 8:125-228.
Hutchinson, G., 1957. Concluding remarks. Cold Spring Harbor Symp., Quant. Biol., 22:415-427.
Hulten, E., 1968. Flora of Alaska and Neighboring Territories. Stanford University Press, 1008 p.
McGraw, J.B. and Antonovics, J., 1983. Experimental ecology of Dryas octopetala ecotypes. J. Ecol., 71:879-897.
Porsild, A.E., 1966. Contributions to the flora of southwestern Yukon Territory. Contributions to Botany IV, Bull. 216, Nat. Mus. Can., Ottawa, p. 1-86.
Porsild, A.E., 1974. Materials for a Flora of Central Yukon Territory. Publications in Botany 4, Nat. Mus. Can., Ottawa, 77 p.
Price, L.W., 1971. Vegetation, microtopography and depth of active layer on different exposures in subarctic alpine tundra. Ecology, 52:639-647.
Raup, H.M., 1953. Some botanical problems of the Arctic. Arctic, 6:68-74.
Roy, A.P., 1987. Spatial Distribution and Dynamics of Dryas (Rosaceae) in Southwestern Yukon. M.A. Thesis, in prep.
Savile, D.B.O., 1972. Arctic Adaptions in Plants, Agriculture Canada, Monograph 6, 81 p.

ÉVOLUTION STRUCTURALE DES TALUS D'ÉBOULIS, LAC À L'EAU CLAIRE, QUÉBEC SUBARCTIQUE

Nicolas St-Cyr

Département de géographie et Centre d'études nordiques, Université Laval, Ste-Foy, Québec G1K 7P4

Niveau: Doctorat

Résumé

Le secteur d'étude est constitué des onzes îles formant l'anneau central du bassin ouest du lac à l'Eau Claire dans le Québec subarctique. Les îles, composées de brèche volcanique, présentent une configuration structurée par la répétition d'une forme de coupole éventrée en son centre. Les flancs des coupoles sont tronqués de falaises vives qui alimentent de nombreux talus d'éboulis. Une typologie des talus d'éboulis est proposée à partir de l'apparence dynamique de la paroi. L'ablation des parois est étudiée en regard des variations du dispositif fissural qui s'avère en étroite relation avec les volumes morphologiques des îles. Les formes d'accumulation, principalement des tabliers et des cônes d'éboulis, et les traces des événements du quaternaire récent tendent à démontrer que l'accumulation a connu des phases beaucoup plus actives (pédiplanation) que ce qui prévaut actuellement et qui peut être qualifié d'activité faible ou d'altiplanation. Les processus de cryoclastie sont efficaces dépendemment de leur association au dispositif fissural. Des mouvements secondaires mais non négligeables retardent la stabilisation de certains talus. Il s'agit des glissements de matériel par gravité, de la solifluxion et des actions littorales et glacielles. L'ensemble des observations, dont les indices biogéographiques, suggère que l'évolution des talus d'éboulis témoigne d'un transfert de la pédiplanation vers l'altiplanation, ce qui est en accord avec le modèle hudsonien (RITCHOT, 1975).

Mots-clés: Talus d'éboulis, évolution, modèle Hudsonien, forme, dispositif fissural, ablation, accumulation, agents d'érosion.

Abstract

The study deals with the evolution of the rocky slopes of the central islands of Lac à l'Eau Claire in subarctic Québec. It appears that the local screes are boundary forms which provide information on the structure of the land forms and their evolution. The various types of scree and the traces of events occurring in the recent Quaternary tend to show that the process of accumulation has, in certain phases (pediplanation), been much more active than it is in its present stage, which can be termed low activity or altiplanation. The study reveals that, while the evolution of the screes depends on a complex of factors, the relations between these factors are determined by the morphological mass inserted into the rock face. Thus, the fissure pattern in the rock face is directly related to the form of the islands' features. The cryoclastic processes become effective to the extent of their association with the fissure pattern. This type of association can be applied to the analysis of the morphometric characteristics of the clasts and their role in the stabilization of the screes. There are also significant secondary movements which delay the stabilization of the screes, viz.: mass movements of material, solifluction, lacustrine agents and the type of forest cover. In sum, these observations indicate a transfer from pediplanation to altiplanation, which is in accordance with the Hudsonian model (Ritchot, 1975).

Key words: Screes; evolution; Hudsonian model; form; fissure pattern; ablation; accumulation; agents of erosion.

Submitted to la revue Géographie Physique et Quaternaire.

LAKE EVAPORATION IN THE HUDSON BAY LOWLANDS

James David Smith

Department of Geography, York University, North York, Ontario M3J 1P3

Level: Master's

Abstract

The evaporation from a small lake in the Hudson Bay Lowlands was studied using an energy balance technique and compared with the evaporation from an adjacent, upwind, land surface. Evaporation of a lake in an advective environment appears to be not only a function of its own available energy but also of the energy of the upwind surface and varies as a function of the distance from the boundary of the two surfaces. It was found that the advective effect of the surrounding tundra resulted in observed Priestley-Taylor α values as high as 1.58. In addition the relative evaporation over the lake along a wind transect, shows a difference in evaporation of 34% between a point 150 m from the upwind shoreline to the opposite edge. These results suggest that to achieve reliable estimates for the Hudson Bay lowlands, advective enhancement should be assessed.

Key words: Evaporation, Hudson Bay Lowlands, advection, microclimatology, lakes.

Résumé

L'evaporation d'un petit lac dans la region de la Baie d'Hudson a été etudiée utilisant une technique de conservation d'énergie. Des comparaisons avec l'évaporation du terrain adjacent ont été effectuées. L'évaporation d'environnements advectifs ne semble pas être seulement une fonction de l'énergie disponible à cet effet, mais aussi de l'énergie de la surface adjacente. L'évaporation varie selon la distance du bord du lac. L'effet advectif de la toundra locale résulte dans l'observation de valeurs aussi élevées que 1.58 pour le paramêtre Priestley-Taylor. En plus, l'évaporation relative au-dessus du lac, dans la direction du vent, démontre une différence dans l'évaporation de 34% entre un point à 150 m du bord du lac et la rive opposée.

Mots-clés: Évaporation, terres-basses de la baie d'Hudson, advection, microclimatologie, lacs.

1. Introduction

Evaporation from natural water bodies and vegetated land surfaces is a major phase of the hydrological cycle. Evaporation and precipitation govern the amount of runoff from a watershed or river basin. Unfortunately, the process of evaporation from open water bodies and from vegetated land surfaces is poorly understood.

The measurement of evaporation is difficult. The rates of water loss are small, typically about 4 mm day^{-1}, and the vertical transport mechanisms are not fully understood. One of the factors least understood is the role that advected energy plays in the evaporation process. Consisting of both a mosaic of terrain types and varying surface energy balances, the arctic region presents an environment conducive to advection. This paper will address the problem of advection in evaporation studies in a northern environment. A concise review of the theory is followed by details of a field experiment conducted in the Hudson Bay Lowlands.

2. Theory

A commonly used method of measuring evaporation is the Bowen ratio energy balance technique. The latent heat flux, QE_β, is:

$$QE_\beta = \frac{Q^* - Q_g}{1 + \beta} \qquad (1)$$

where $\beta = (\gamma \Delta T / \Delta e)$; ΔT is the vertical change of temperature (K); Δe is the vertical change of vapour pressure (kPa); γ is the psychrometric constant (0.066 kPa K^{-1}); Q^* is the net radiation flux (W m^{-2}); and Q_g is the soil heat flux (Wm^{-2}).

Slatyer and McIlroy (1961) modelled evaporation from a moist surface under conditions of minimal advection. They termed this 'equilibrium evaporation'. This model was derived from the Penman (1948) evaporation model and can be written as:

$$QE_{eq} = \frac{s}{s + \gamma} (Q^* - Q_g), \qquad (2)$$

where s is the slope of the saturation vapour pressure-temperature curve (kPa K^{-1}).

Priestley and Taylor (1972) suggested an empirically derived coefficient (α) to correct for minimal advection using the equilibrium model. The value of α can be determined by taking the ratio of the calculated Bowen ratio evaporation and equilibrium evaporation;

$$\alpha = \frac{QE_\beta}{QE_{eq}} = \frac{s + \gamma}{s(1 + \beta)} \qquad (3)$$

Priestley and Taylor (1972) found $\alpha = 1.26$ on average for large, saturated, land and advection-free water surfaces.

The last decade has seen numerous field experiments conducted in order to gain a better understanding of the evaporation parameter α, but only limited work has been done in the North. Stewart and Rouse (1976) studied evaporation from shallow lakes and ponds, and later for saturated sedge meadow (Stewart and Rouse, 1977). They obtained α values of 1.26. This value of α is also substantiated by Marsh, Rouse and Woo (1981) over a frozen gravel surface near Resolute, N.W.T. However, Roulet and Woo (1986) found α values as high as 1.60 for a valley wet-land in central

Keewatin. Singh and Taillefer (1986) also found that α was greater than 1.26 during periods of warm air advection over a black spruce forest in subarctic Quebec. Similar studies conducted in non-Arctic regions suggest that α can range from 0.53 to 2.08, depending on the surface type, availability of water, prevailing weather conditions and the size of the surface (Barton, 1979; deBruin and Keijman, 1979; Davies and Allen, 1973; McCaughey, 1978; McNaughton and Black, 1973; Mukamal *et al.*, 1977; Shuttleworth and Calder, 1979).

The introduction of advection alters the modelling approach. Consider an air mass moving from a uniform, dry, surface to a water surface. All the lower boundary conditions change abruptly at the division between the two surfaces. The surface humidity is greatly increased and the surface roughness and temperature are, in general, likely to be different. The vapour flux immediately behind the leading edge of the water surface is considerably larger than its value over the land surface. This results in a discontinuity in the thermal and water vapour stratification which should produce a rapid change in the stability of the atmosphere and the sensible heat transfer. The mean wind profile and the turbulent structure of the air must therefore adjust to compensate for the new, downwind, surface roughness and changes in stratification. The turbulent structure, however, controls the transport mechanisms and therefore, in turn the temperature and humidity profiles. Behind the boundary, the vertical profiles are no longer in equilibrium. Only further downwind will the profiles of specific humidity, wind velocity and temperature tend to a new equilibrium with the new surface conditions and the gradients will become vertical once again.

In order to account for local advection on evaporation, McNaughton (1976a, b) suggested the following formula:

$$QE = \frac{s}{s + \gamma}(Q^* - Q_g) + \frac{\Psi}{s + \gamma} \qquad (4)$$

where $\Psi = a^* QH + QE$, a^* is a site-specific constant. The second term on the right is the advection enhancement term (W m^{-2}) which varies with upwind surface moisture availability and distance from the surface moisture discontinuity. QH is the fraction of Q* used in sensible heat transfer.

3. The nature of the study area

This study was conducted during the summers of 1985 and 1986 on a small lake in the Hudson Bay Lowlands 60 Km south of Churchill, Manitoba (58° 10′ N, 93° 57′ W). The region comprises featureless, gently sloping, wet fen and peat plateau. The peat deposits are about 2 m thick and consist of moderately fibrous, horizontally matted, yellow or brown moss layers, interspaced with darker, more decomposed fen peat (Dredge, 1979). The surface of the peat is characterized by high centre polygons defined by a system of ice wedge troughs many of which are filled with water. Low centre polygons are present as secondary features (Dredge and Nixon, 1979). The peat is almost completely covered with a 10 cm thick lichen mat.

The area also contains numerous, shallow, flat-bottomed ponds several tens of metres across. A visual estimate indicates approximately 50% lake cover. These ponds are underlain by peat and are usually less than 1 m deep. Large elongated lakes more than 1 km long are also common features. These large lakes have silty sediments around the edges, are flat-bottomed and less than 3 m deep. These lake bottoms are covered by a dark layer of disseminated peat fibres.

4. Methods and measurements

Two sites were instrumented, one located on a peat plateau with sufficient fetch to keep local advective effects to a minimum, and the other in the middle of a small lake (600 × 250 m, 1.25 m deep). The evaporative flux from both sites was calculated using the Bowen ratio technique.

The net radiation (Q*) was measured using net radiometers (Middleton). Q_g was determined for the land site and the lake bottom using soil heat flux plates. The additional component of the heat flux into the lake (Q_w) was calculated from a thermistor profile through the lake (Yellow Springs instruments, accurate to +/−0.2°C), using:

$$Q_w = \sum_{i=1}^{Z} \rho_w C_w z_i \frac{\Delta T_i}{\Delta t} \qquad (5)$$

where $\rho_w C_w$ is the heat capacity of water; $\Delta T_i/\Delta t$ is the change in temperature over time at level i; z_i is the thickness of slab i; Z is the number of thermistor slabs. The Bowen ratio was determined at both sites using shielded, aspirated, thermopile psychrometers mounted at 0.5 and 1.0 m above each surface. Readings were taken every 10 s and averaged each hour using Campbell CR7 data recorders. The effect of the land on the lake evaporative regime could then be determined by direct comparison.

The relative change in lake evaporation along a wind transect was measured using 16 Piche evaporimeters located at heights of 0.5 and 1.0 m above the water surface for 8 locations (one of the locations being the same as the instrumentation for the Bowen ratio determination). Piche evaporimeters consist of an inverted graduated cylinder. Water loss evaporated from a filter was recorded twice per day.

5. Results

The value of α was calculated over the lake using equation (3). It was found that α varied from 1.05 to 1.58. It was also found to increase directly as the lichen cover over the upwind land dried out and to decrease as lichens became saturated, as after a rainfall event. Typical results are shown in Figure 1. July 8, 1985 was a completely cloud-free day with net radiation reaching a maximum of 722 W m^{-2} at solar noon. At 0600 on July 9 an intermittent rain began and the skies cleared around 1400. With a morning dewform on July 8, the lichen surface was saturated until sunrise when the surface began to evaporate. The α parameter increased to a value of 1.58 and fell back to its previous night-time value. It should be noted that α did not peak at the maximum net available energy but at a point later when the upwind air had been dried most of the day. The α parameter was not affected by the fluctuation of $Q^* - Q_g$ from the land during the rain on July 9 since the lichen surface was saturated throughout

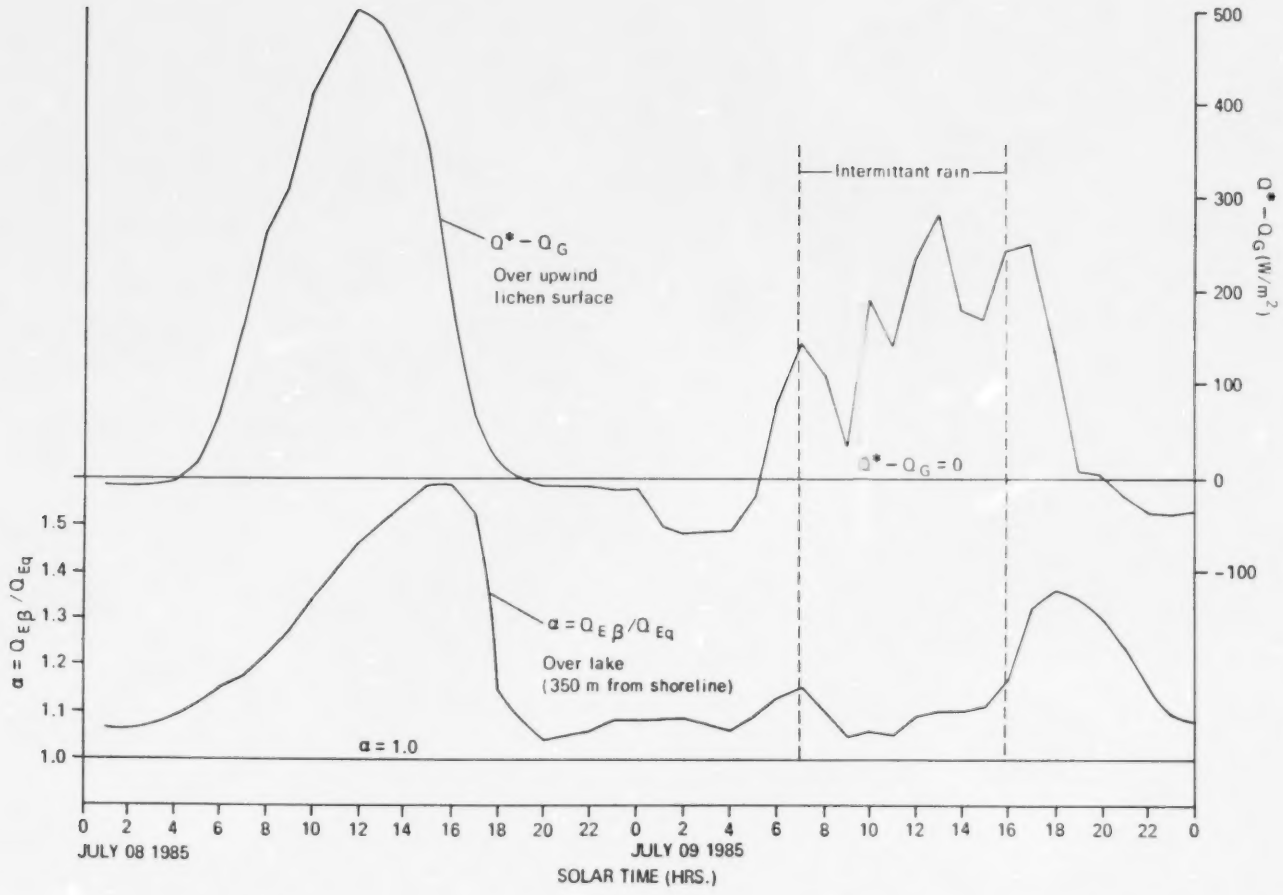


Figure 1. Calculated Priestley-Taylor α parameter for a small lake in the Hudson Bay Lowlands and net available energy ($Q^* - Q_g$) over an adjacent upwind tundra surface versus time for the period July 8 and 9, 1985.

the time period. There was a slight but rapid increase in α after the land surface began to dry after the rain.

The data from the Piche evaporimeters indicated that there was increased evaporation near the upwind shoreline when the air advected from the land surface is warm and dry. Figure 2 shows relative evaporation totals (ml) as a function of position on the lake for two time periods, 1900 June 27 to 0900 June 28 and 0900 to 2000 June 28, 1985. For the day time period there was a 34% increase in evaporation between a point 150 m from the upwind shoreline and the downwind shore where the advective influence of the land is at a minimum. There was almost no change in evaporation across the lake during the night. This can be expected since the previous figure showed that there was little advection at this time. Data closer than 150 m to the shoreline could not be used because a grove of spruce trees interrupted the mean wind flow.

6. Discussion

The fluctuating value of α obtained in this study seems, at first, to contradict the work of Stewart and Rouse (1976). They obtained a consistent value of $\alpha = 1.26$ for a shallow subarctic lake near the coast of Hudson Bay. The difference could be due to fact that the upwind surface of the Stewart and Rouse study may have been close to freely evaporating, especially when the winds were blowing off the Bay. The upwind surface of the present study, however, recorded Bowen ratio values of as large as 2.0 which is the lower limit of semi-arid desert values (Oke, 1978:59). These large Bowen ratio values may be due to the fact that the lichens (*Cladonia* spp.), which make up most of the ground cover, are non-vascular and as such do not transpire and block, to some extent, the turbulent transport of water vapour from the surface.

The work of Roulet and Woo (1986) shows α values as large as 1.60 for a wetland surface. They measured the evaporation within 100 m of an upwind lichen-dominated peat surface. It is perhaps not surprising that the present study shows similar values if the increased evaporation is indeed due to local scale advection.

If, under conditions of minimal advection, freely evaporating surfaces evaporate 26% more than equilibrium, due possibly

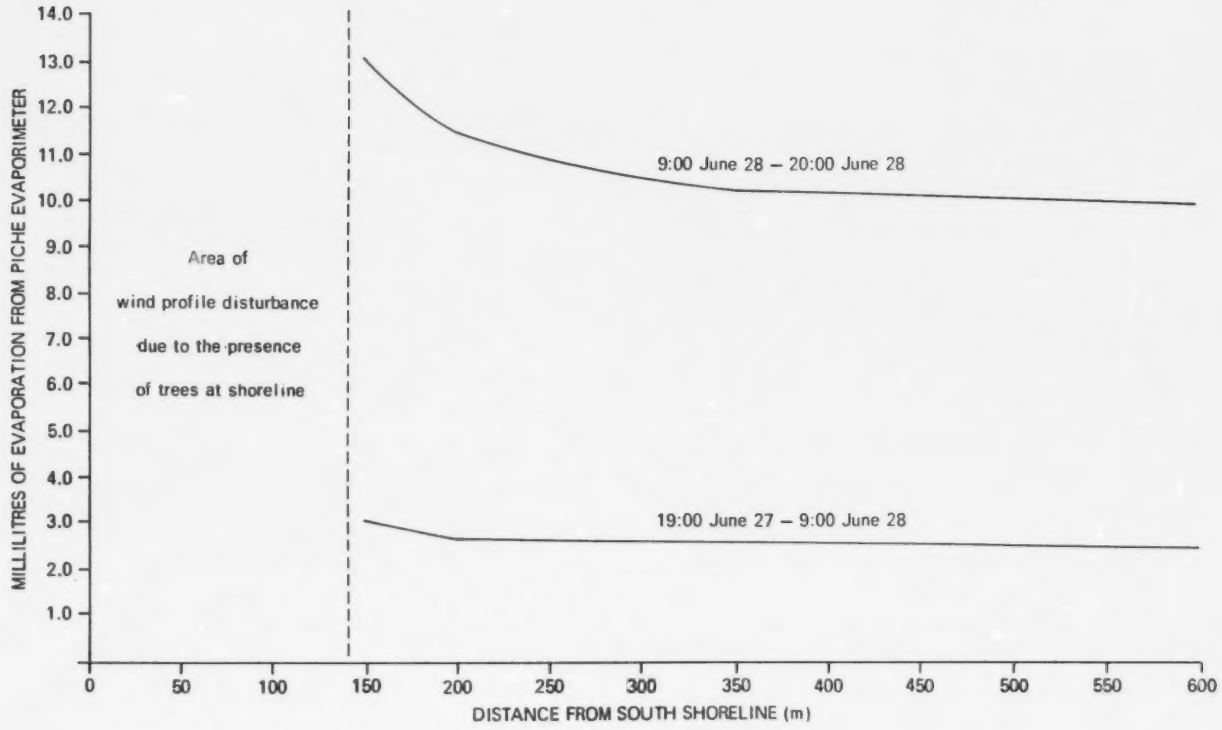


Figure 2. Relative evaporation measured with Piche evaporimeters versus distance from the upwind leading edge for a small lake. Two separate time periods are shown; 1900 June 27 to 0900 June 28 and 0900 June 28 to 2000 June 28, 1985.

to cloud condensation and vertical flux divergence then, in addition, the advection enhancement term of McNaughton's model (1976a) for this study, was as much as 32% of equilibrium, at a point 350 m from the upwind shoreline.

It should be noted here that results shown in this study are only for a few specific days in the summer of 1985. The complete data set, encompassing approximately 260 days over two years, has yet to be completely analyzed. This study reveals some noteworthy observations. There appears to be a definite feedback mechanism between land and lake evaporation, a decrease in the one leads to an increase in the other. Any future changes to the hydrologic regime of the northern environment could affect the microclimate by changing the amount of energy that is used in evaporation. As an example, increasing the water table could cause a reduction in lake evaporation by making land surface water more accessible to the atmosphere.

Another important observation is that the effect of the surrounding land on lake evaporation is a function of distance from the upwind shoreline. This appears to be evident from Figure 2. This means that several small lakes, each with diameters of, say, 200 m should evaporate more than one large lake with a surface area equal to the combined area of the others. The size and spacing of the lakes then has an effect on the amount of evaporation from an area.

7. Conclusions

This study shows that lake evaporation in the Hudson Bay Lowlands is directly affected by the evaporation of the surrounding landscape. The study of evaporation in this region should include a study of all the various terrain types and their relative spacing with relation to each other. For this area it does not appear that the use of a constant value of α would accurately estimate evaporation at this time. A better physical understanding of the α parameter may lead to a better understanding of evaporation processes in highly advective environments.

Acknowledgments

I wish to thank D. Joiner, L. Kongsrude, T. Papakyriakou, R. Peluso and C. Prophet for their assistance in collecting the data used in this study. I am also grateful to Drs. R. Bello and N. Roulet for their invaluable comments on the manuscript. I would like to thank the Churchill Northern Studies Centre for their logistical support and the Department of Indian and Northern Affairs, through their Northern Scientific Training Program, for financial support. Research was supported by an NSERC grant to R.L. Bello. The loan of the data loggers by W.R. Rouse was also greatly appreciated. Thanks also to Y. Rochon for his comments and translation.

References

Barton, I.J. 1979. A parameterization of the evaporation from nonsaturated surfaces. The Journal of Applied Meteorology 18:43–47.

Davies, J.A., and Allen, C.D. 1973. Equilibrium, potential, and actual evaporation from cropped surfaces in southern Ontario. The Journal of Applied Meteorology 12:649–647.

Debruin, H.A.R., and Keijman, J.Q. 1979. The Priestley-Taylor evaporation model applied to a large, shallow lake in the Netherlands. The Journal of Applied Meteorology 18:898-903.

Dredge, L.A. 1979. Thaw depths and permafrost in polygonal peat terrain, Hudson Bay Lowland, Manitoba. In current research, part c, Geological Survey of Canada, paper 79-1c:27-30.

Dredge, L.A., and Nixon, F.M. 1979. Thermal sensitivity and the development of tundra ponds and thermokarst lakes in the Manitoba portion of the Hudson Bay Lowlands. In current research, part c, Geological Survey of Canada, paper 79-1c:23-26.

Marsh, P., Rouse, W.R., Woo, M.-K. 1981. Evaporation at a high arctic site. The Journal of the Atmospheric Sciences 20(6):713-716.

McCaughey, J.H. 1978. Energy balance and evapotranspiration estimates for a mature coniferous forest. Canada Journal of Forestry Research 8:456-462.

McNaughton, K.G. 1976a. Evaporation and advection I: evaporation from extensive homogeneous surfaces. The Quarterly Journal of the Royal Meteorological Society 102:181-191.

McNaughton, K.G. 1976b. Evaporation and advection II: evaporation downwind of a boundary separating regions having different surface resistances and available energies. The Quarterly Journal of the Royal Meteorological Society 102:193-202.

McNaughton, K.G., and Black, T.A. 1973. A study of evapotranspiration from a Douglas Fir forest using the energy balance approach. Water Resources Research 9:1579-1590.

Mukammal, E.I., and Neumann, H.H. 1977. Application of the Priestley-Taylor evaporation model to assess the influence of soil moisture on the evaporation from a large weighing lysimeter and Class A pan. Boundary Layer Meteorology 12:243-256.

Roulet, N.T., and Woo, M.-K. 1986. Wetland and lake evaporation in the low arctic. Arctic and Alpine Research 18:195-200.

Oke, T.R. 1978. Boundary Layer Climates. London: University Paperbacks. 372 p.

Penman, H.L. 1948. Natural evaporation from open water, bare soil, and grass. Proceedings of the Royal Society of London, Ser. A 193:120-145.

Priestley, C.B.H., and Taylor, R.J. 1972. On the assessment of surface heat flux evaporation using large-scale parameters. The Monthly Weather Review 100:81-92.

Singh, B., Taillefer, R. 1986. The effect of synoptic-scale advection on the performance of the Priestley-Taylor evaporation formula. Boundary Layer Meteorology 36:267-282.

Shuttleworth, W.J., and Calder, I.R. 1979. Has the Priestley-Taylor equation any relevance to forest evaporation? The Journal of Applied Meteorology 18:639-646.

Slatyer, R.O., and McIlroy, I.C. 1961. Practical meteorology. CSIRO, Melbourne. 310 p.

Stewart, R.B., and Rouse, W.R. 1976. A simple method for determining the evaporation from shallow lakes and ponds. Water Resources Research 12:623-628.

Stewart, R.B., and Rouse, W.R. 1977. Substantiation of the Priestley and Taylor parameter $\alpha = 1.26$ for potential evaporation in high latitudes. The Journal of Applied Meteorology 16:649-650.

PHYSIO-CHEMICAL EVALUATION OF WATER IN TUNDRA PONDS AND PRECIPITATION SAMPLES FROM IQALUIT (FROBISHER BAY), N.W.T., JULY 1985

Janet Stavinga

Department of Geography, McGill University, Montreal, Quebec H3A 2K6

Level: Bachelor's

Abstract

An assessment of the susceptibility of arctic tundra ponds in the vicinity of Iqaluit (Frobisher Bay) to contamination via the atmospheric transport of pollutants was conducted during July 1985. This was achieved through the collection and analysis of surface water samples from several large tundra ponds as well as precipitation samples from the community of Frobisher Bay. Additional samples were collected from Nettilling Lake and the surrounding area for comparative purposes.

The chemical analyses of the surface water samples from Frobisher revealed low alkalinity values indicating a relatively low capacity to resist acidification. Analyses of bulk precipitation from Frobisher Bay and Nettilling Lake showed detectable levels of lead and cadmium. Lead levels were higher in Frobisher than Nettilling. It is thought that the higher lead levels are a consequence of vehicular traffic within the community itself. Local sources may account for the concentrations of cadmium measured in Frobisher Bay however, not those levels measured near Nettilling Lake. These elevated concentrations provide indirect evidence for the long range transport of cadmium.

These heavy metals were not detected in the surface waters sampled however, since these metals are insoluble it is more probable that they would be found in the sediments.

Key words: Surface water chemistry, precipitation, atmospheric transport, anthropogenic pollution, Baffin Island, N.W.T..

Résumé

L'auteure a effectué, en juillet 1985, une évaluation de la sensibilité des étangs de la toundra arctique des alentours de Iqaluit (Frobisher Bay) à la contamination par les polluants industriels transportés par l'atmosphère. Elle a recueilli et analysé des échantillons d'eaux superficielles dans plusieurs étangs de la toundra, ainsi que des eaux de pluie recueillies dans la localité de Frobisher Bay. D'autres échantillons avient été recueillis au lac Nettilling et dans ses alentours pour fin de comparaison.

L'analyse chimique des échantillons d'eaux superficielles prélevés à Frobisher Bay a montré leur faible alcalinité, qui les rend peu aptes à résister à l'acidification. L'analyse des eaux de précipitation recueillies à Frobisher Bay et au lac Nettilling a mis en évidence des quantités détectables de plomb et de cadmium. Les taux de plomb étaient plus élevés dans l'eau de précipitation de Frobisher que dans celles recueillies au Nettilling. On croit que ce taux plus élevé est dû à la circulation automobile dans la localité elle-même. Des sources locales de pollution peuvent expliquer les teneurs en cadmium mesurées à Frobisher Bay, mais non celles relevées au lac Nettilling. Ces fortes concentrations constituent

une preuve indirecte du transport atmosphérique du cadmium sur de longues distances.

Cependant, ces métaux lourds n'ont pas été détectés dans les échantillons d'eaux superficielles; comme ces métaux sont insolubles, il est probable qu'on les retrouverait dans les sédiments.

Mots-clés: Chimie des eaux superficielles, eaux de précipitation, transport atmosphérique, pollution anthropogénique, île de Baffin, T.N.-O.

Introduction

It is generally accepted that air pollutants may be transported distances of 1000 to 2000 km through the atmosphere (Overrein, 1976). Kerr (1981) proposed that air masses travelling from Central USSR across Western Europe may incorporate pollutants from these heavily industrialized areas and deposit them in arctic regions. Trace metals such as sulphate and vanadium have been detected as far west as Barrow, Alaska, Mould Bay, 1300 km northeast of Barrow, and Igloolik, 2500 km east of Barrow. Vanadium is present naturally in dust particles, but the amount detected in parts of the arctic was well above that contributed naturally (Kerr, 1981).

Hobbie (1980) states that the physical and the chemical analyses of tundra ponds really began with the establishment of research stations at Disko Bay, Greenland and Barrow, Alaska in the 1950's. However, most of the studies (Livingstone *et al.*, 1958; Oliver, 1964; Kalff, 1968; Roy, 1979) have failed to take into account the contribution of atmospheric inputs to the chemical composition of natural waters.

There is a wealth of information on chemical concentrations in aquatic systems and their relation to atmospheric inputs in Europe (Overrein, 1976; Wright and Henriksen, 1978) as well as in Northern Ontario, especially in the area of Sudbury (Beamish and Van Loon, 1977). However, the literature is lacking in studies completed in the arctic region. The only significant study was conducted by McNeely and Gummer (1984) in response to the increased frequency of arctic haze. McNeely and Gummer analyzed snow-pack, precipitation and surface water samples from the eastern part of Ellesmere Island in an attempt to gather evidence to support the long range atmospheric transport of pollutants. They determined that, because the surface waters had a very low alkalinity and were probably ombrogenic, chemical changes in the atmospheric aerosols would have a significant impact on the chemical composition of these surface waters.

The eastern part of Baffin Island has the highest annual precipitation of the Arctic Islands with winds predominantly from the northwest and southeast (Maxwell, 1980). Bingham (1984) measured lead and cadmium levels in rainfall at six sites around Frobisher Bay during the summer of 1983. She found detectable levels of cadmium in ten out of fourteen samples and of lead in four, with the highest levels near areas of high vehicular traffic. Whether the presence of these trace contaminants is a result of local sources or long range atmospheric sources is unknown, but it was suspected that these contaminants would be present in the water of nearby ponds.

It is with these facts in mind that my study focuses upon assessing the susceptibility of arctic tundra ponds in the vicinity of Frobisher Bay to contamination via the atmospheric transport of pollutants. The general objectives of my study are: 1. To obtain basic chemical data on several large tundra ponds through surface water sampling; and 2. To collect and analyze precipitation samples from the community of Frobisher Bay.

Figure 1. Study Area: Baffin Island, N.W.T., July 1985.

Methodology

Study Area

The study area is located within the vicinity of the community of Iqaluit (Frobisher Bay), Northwest Territories. Additional samples for comparative purposes were collected from Nettilling Lake and the surrounding area, which is located approximately 300 km northwest of Frobisher Bay (Figure 1). Frobisher Bay lies within the Canadian Shield which is composed primarily of igneous rocks whereas the areas sampled near Nettilling Lake are located within the Arctic Platform as well as the Canadian Shield. The former is composed of Paleozoic sediments (Thorsteinsson and Tozer, 1976).

Study Period and Sampling Methods for Surface Water Sampling

Surface water samples were collected from eleven tundra ponds in the vicinity of Frobisher Bay from 3–17 July 1985. Surface water samples from the Nettilling Lake area were collected between 27 June to 3 August 1985. Surface water sampling, preservation and analysis followed the procedures outlined in the *Analytical Methods Manual* (Environment Canada, 1979).

Each tundra pond within the Frobisher Bay area was sampled at two sites to evaluate the homogeneity of the pond. Figure 2 shows the locations of the ponds sampled.

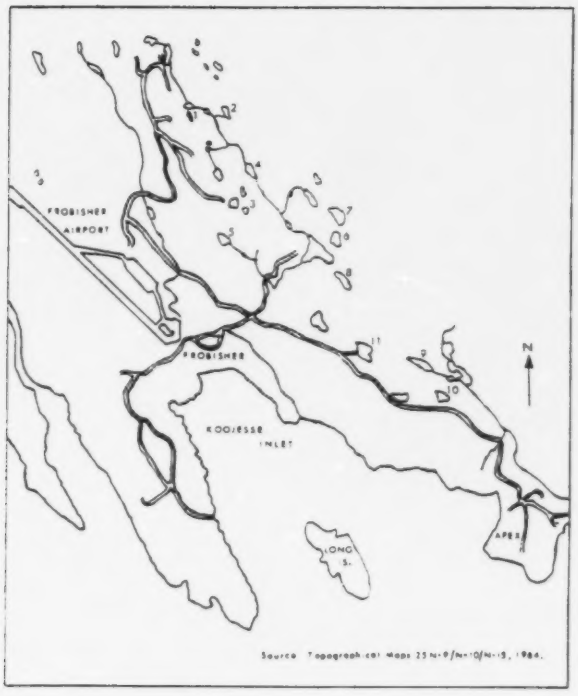


Figure 2. Location of the Tundra Ponds Sampled Near Frobisher Bay, July 1985.

Field Parameters

Parameters measured in the field at each site in the vicinity of Frobisher Bay were water temperature at the surface, pH and conductivity. Conductivity and pH were determined using an Environmental Multi-Probe. Conductivity values were measured in mhos cm^{-1} and had to be converted to $uScm^{-1}$ and standardized to 25°C.

Laboratory Analyses

Other parameters were determined in the laboratory in Frobisher Bay and at the University of Windsor. Parameters that were analyzed at Ikaluit Laboratory in Frobisher Bay were total alkalinity and chloride. Total alkalinity was determined by indicator methods, following the procedures outlined in *Standard Methods for the Examination of Water and Waste Water* 13th Edition (1974). Chloride concentrations were estimated by the argentometric method outlined in the *Standard Methods for the Examination of Water and Waste Water* 13th Edition (1974). Sulphate concentrations were determined using the turbidimetric method and a Spectronic 20 Colorimeter following the procedure outlined in *Hach Procedures for Water Sewage and Analysis*.

TABLE 1
Inorganic Parameters Analyzed

Parameters	D.L.*
Calcium	0.03
Cadmium	0.0005
Copper	0.001
Iron	0.02
Lead	0.003
Magnesium	0.001
Manganese	0.001
Potassium	0.004
Sodium	0.002
Zinc	0.004

*D.L. - Analytical Detection Limit (mgl^{-1})

Concentrations of ten elements in the surface waters were determined using the IL 51 Series Flame Atomic Absorption Spectrophotometer (AAS) Model No. 351 at the Geography Department, University of Windsor. Table 1 lists the parameters measured and their detection limit. Sample blanks were included to evaluate the quality of the analyses.

Study Period for Precipitation Collection

Two one litre polyethylene bottles were placed outside Ikaluit Lab in Frobisher Bay from 27 June to 17 July, 1985 to collect bulk precipitation. Bulk precipitation samples were also collected from 27 June to 10 July 1985 and from 10 July to 3 August 1985 from the Nettilling Lake area.

Laboratory Analyses

Alkalinity, chloride and sulphate concentrations were not measured from the precipitation data due to the various constraints of the tests such as the volume required. However, precipitation samples were analyzed for the same ten elements as the surface waters using the AAS.

The results from the Frobisher Bay area were compared to surface water and precipitation samples collected and analyzed from the surrounding area of Nettilling Lake, 300 km northwest of Frobisher Bay and remote from any human habitation.

Results and Discussion

Classification of Ponds by Acidity and Calcium Content

Henriksen (1977) developed an empirical curve used to determine whether a water body is acidified or unacidified. This curve was derived from Henriksen's research of northern and northwestern lakes in Norway. The curve is based on measured pH and calcium concentrations. This curve was applied effectively to lakes in Scandinavia in the western and central part of Sweden and in North America in areas such as the Experimental Lakes Area (ELA) in Northwestern Ontario, the Adirondack Mountains in New York and in Sierra Nevada, California.

Calcium and pH values determined from the Frobisher Bay area were plotted against Henriksen's empirical curve. From Figure 3 one can see that the majority of the observations are below Henriksen's linear regression curve, indicating unacidified waters. However, two ponds located near the road to Apex were considered acidified since they lie above the empirical curve. It should be remembered that this empirical relationship must be verified with respect to Frobisher Bay's altitude, morphology and lithology (Environment Canada, 1981).

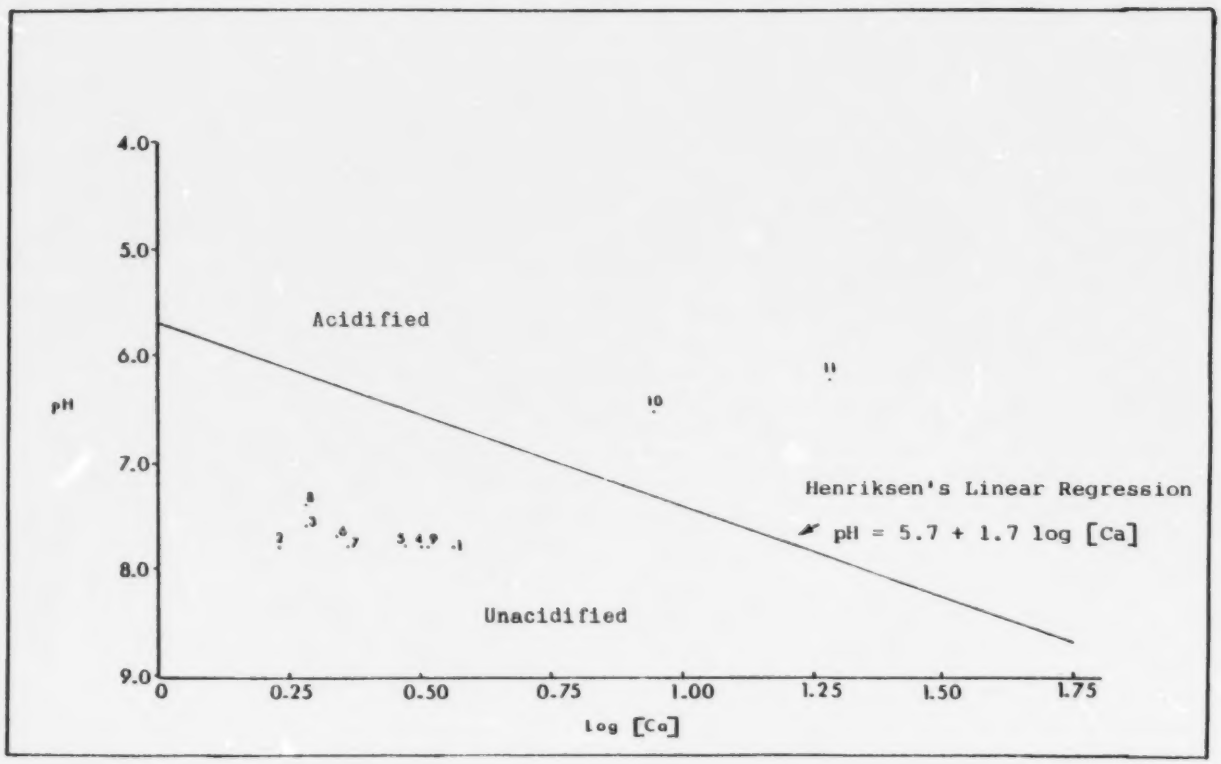


Figure 3. Classification of the Tundra Ponds by Acidity and Calcium Content, Frobisher Bay, July 1985

Alkalinity

Alkalinity refers to the ability of a water body to resist acidification or, the neutralizing of buffering capacity of the water body. A water body with an alkalinity of less than 30 $mg1^{-1}$ $CaCO_3$ possesses very low concentrations of neutralizing components (Novotny and Chesters, 1981).

Precambrian rocks such as granite and gneiss are very resistant to weathering and therefore their capacity to neutralize acidic inputs is reduced (Gorham, 1976). This is significant when one remembers that Frobisher Bay is located within the Canadian Shied.

The tundra ponds in the vicinity of Frobisher Bay had alkalinity values ranging from 5.67 – 49.67 $mg1^{-1}$ $CaCO_3$. Ten of the ponds ranged from 5.67 – 23.8 $mg1^{-1}$ $CaCo_3$. Only one pond, Pond 11 located near the road to Apex had a value of 49.67 $mg1^{-1}CaCO_3$. These values seem to indicate that these ponds possess a very low capacity to resist acidification. Alkalinity of the samples from Nettilling Lake could not be determined due to the time that had elapsed between sample collection and analysis.

Heavy Metal Analyses of Precipitation

Bulk precipitation gathered from Frobisher Bay and Nettilling Lake showed detectable levels of lead and cadmium. The concentrations of lead in the precipitation were greater for the Frobisher Bay samples (11.9 $ug1^{-1}$) than the samples found from the Nettilling Lake area (3.74 $ug1^{-1}$). This may be explained by the proximity of the precipitation collector in Frobisher Bay to the community itself. Bingham (1984) analyzed precipitation samples from six sites which differed with respect to their distance from the community of Frobisher Bay. Bingham found reduced levels of lead in the samples as distance from the community increased. During the 1985 study period the sampler was located on the roof of Iqaluit Lab within the community itself. It is quite possible that the elevated concentrations of lead were a consequence of vehicular traffic within the community. This would account for the decrease in lead concentrations as one moves northwest to Nettilling Lake, an isolated and uninhabited area.

Both Frobisher Bay and Nettilling Lake bulk precipitation samples had similar cadmium concentrations. Local sources in Frobisher Bay could account for the levels detected within the community, but not those levels found in the Nettilling Lake area. It is highly probable that these concentrations exist due to the long range atmospheric transport of cadmium.

The levels of cadmium and lead detected from Frobisher Bay and Nettilling Lake appear to be within range of the concentrations measured by Sanderson and Marchand (1984) for urban and rural sites within Essex County. From Table 2 it is possible to see that the range of lead concentrations detected in the bulk precipitation samples from both rural and urban sites within Essex County is quite large. The mean level of lead for the urban and rural sites is above that detected from the Frobisher Bay and Nettilling Lake samples. However, ranges of urban and rural cadmium concentrations as well as the mean values come much closer to those values detected from the arctic sites.

TABLE 2
Heavy Metal Analysis of Precipitation. A Comparison to Southern Ontario ($ug1^{-1}$).

AREA OF INTEREST	LEAD	CADMIUM
Frobisher Bay	11.90	0.62
Nettilling Lake	3.74	0.57
Essex County (Sanderson and Marchand, 1984)		
Urban	58.30 (3-300)	0.90 (0.2-2.3)
Rural	26.50 (4-55)	0.30 (N.D.-1.0)

N.D. Not Detectable

( ) Range Found

Conclusions

The ponds sampled near Frobisher Bay had low alkalinity values indicating that their ability to resist acidification is also low. The majority of the ponds sampled near Frobisher Bay were considered unacidified using Henriksen's Linear Equation. however, there were two ponds that were considered acidified. This is thought to be a result of local contamination considering the fact that all the other ponds were unacidified.

Precipitation samples from Frobisher Bay and Nettilling Lake showed detectable levels of lead and cadmium. The concentrations of lead detected decreased as one moved from Frobisher Bay to Nettilling Lake giving indirect evidence for local contamination of precipitation from the community of Frobisher Bay. Interestingly, the levels of cadmium detected from the two sampling areas were quite similar. It seems that only the long range atmospheric transport of cadmium would explain the levels observed from the Nettilling Lake area.

These heavy metals were not detected in the surface waters sampled from Frobisher Bay or from the Nettilling Lake area. However, since these metals are highly insoluble it is more probable that if levels of these contaminants were to be detected it would be from sediment samples which were not considered in this study.

It seems highly significant that the levels of cadmium detected from the precipitation samples from Frobisher Bay and Nettilling Lake approximated those levels reported by Sanderson and Marchand (1984) for rural areas in southwestern Ontario. There seems to be evidence that pollutants are being transported to fairly remote areas. Whether the levels detected from Nettilling Lake were a consequence of the pollutants being transported from the community of Frobisher Bay or a more distant source is unknown. But the fact remains that pollutants are indeed present in the atmosphere and can travel some distance before being deposited. The fact that the metals were not observed in the surface waters sampled does not mean they are not present in the water body. Rather the absence of these contaminants should further emphasize the need for a more comprehensive study which would include sediment analysis.

Acknowledgments

I am grateful to Dr. J. Jacobs, for it was he who encouraged me to conduct my research in the Arctic. He also provided constructive criticism of my research findings. I am indebted to Mr. Patrick McQuarrie who spent many long hours helping in the field preparation as well as the laboratory analyses. I also appreciate the assistance of Mr. Rick Dumala who designed my sampling rod, aided in the determination of certain chemical parameters and who was also there when I had computer problems. Thanks are also extended to Mr. Ron Welch for his cartographic advice.

Finally, I would like to thank the Northern Scientific Training Program of the Department of Indian and Northern Affairs and the Natural Sciences and Engineering Research Council of Canada for the funding which allowed me to perform this research.

References

American Public Health Assoc., American Water Works Assoc. and the Water Pollution Control Federation. 1974. Standard Methods for the Examination of Water and Waste Water, 13th Edition. Washington, D.C.

Beamish, R.J. and J.C. VanLoon. 1977. "Precipitation loading of acid and heavy metals to a small acid lake near Sudbury, Ontario." Journal of the Fisheries Research Board of Canada. 34:649-658.

Bingham, V.G., 1984. Lead and Cadmium in Precipitation: A Comparison of Urban and Rural Essex County and Baffin Island. Unpublished B.A. thesis, Department of Geography, University of Windsor.

Environment Canada. 1979. Analytical Methods Manual 1979. Water Quality Branch, Inland Waters Directorate. Ottawa: Minister of Supply and Services.

_____. 1981. Susceptibility of Aquatic Ecosystems to Effects of Atmospheric Pollutant Fallout in Quebec. Inland Waters Directorate Quebec Region. Ottawa: Minister of Supply and Services.

Gorham, E. 1976. "Acid precipitation and its influence upon aquatic ecosystems — An overview." Water Air and Soil Pollution. 6:457-481.

Henriksen, A. 1979. "A simple approach for identifying and measuring acidification of freshwater." Nature. 278 (5704):542-545.

Hobbie, E. 1980. Limnologyof Tundra Ponds. Stroudsburg, Pa.: Hutchinson and Ross.

Kalff, J. 1968. "Some physical and chemical characteristics of arctic freshwaters in Alaska and Northwest Canada." Journal of the Fisheries Research Board of Canada. 25:2575-2587.

Kerr R.A. 1981. "Pollution of the arctic atmosphere confirmed." Science. 212(4498):1013-1014.

Livingstone, D.A., K. Bryan Jr. and R.G. Leaky. 1958. "Effects of an arctic environment on the origin and development of freshwater lakes." Limnology and Oceanography. 3:192-214.

Maxwell, J.B. 1980. The Climate Of the Canadian Arctic Islands and Adjacent Waters. Ottawa: Minister of Supply and Services.

McNeely, R.N. and W.D. Gummer. 1984. "A reconnaissance survey of the environment chemistry in East-Central Ellesmere Island, N.W.T." Arctic. 37(3):210-223.

Novotny, V. and G. Chesters. 1981. Handbook of NonPoint Pollution Sources and Management. Toronto: Van Nostrand Reinhold Company — Litton Educational Publishing.

Oliver, D.R. 1964. "A limnological investigation of a large arctic lake, Nettilling Lake, Baffin Island." Arctic. 17:69-73.

Overrein, L.N., 1976. "A presentation of the Norwegian project 'Acid Precipitation — Effects on Forest and Fish'." Water Air and Soil Pollution. 6:167-172.

Roy, A.C., 1979. The Water Quality of Selected Lakes in the Arctic Watershed of Ontario. Toronto: Ministry of the Environment, Northeastern Region and Water Resources Branch.

Sanderson, M. and D. Marchand. 1984. "Lead and cadmium in precipitation in the Essex Region of Southwestern Ontario." Hydrochemical Balances of Freshwater Systems Proceedings of the Uppsala Symposium. IAHS Publication No. 150.

Thorsteinsson, R. and E.T. Tozer. 1976. "Geology of the arctic archipelago." Geology and Economic Minerals of Canada. 548-590. Edited by R.J.W. Douglas. Ottawa: Minister of Supply and Services.

Wright, R.F. and A. Henriksen. 1978. "Chemistry of small Norwegian lakes with special reference to acid precipitation." Limnology and Oceanography. 23:487-498.

A STUDY OF AN ACTIVE LAYER SOIL WITH AN UNUSUAL THERMAL REGIME, NEAR SCHEFFERVILLE, P.Q.: PRELIMINARY RESULTS

K.J.L. Stoker Jr.

Department of Geography, Carleton University, Ottawa, Ontario K1S 5B6

Level: Bachelor's

Abstract

An analysis of the temperature regime of a permafrost soil near Schefferville, P.Q. has been done. The Hematite Lake experimental site involved has alpine tundra vegetation and is underlain by permafrost. As a result of its coarse grain size and mineralogical nature, the active layer has rather unique thermal properties. Consequently, temperatures are influenced much more by water movement than by the diurnal cycle. To study the subsurface, temperature as well as moisture measurements were obtained. The analysis compares the actual heat flow regime with the heat conduction equation emphasizing anomalous 'diffusivities' from which the type of heat transfer can be drawn. This technique is backed up by means of estimating thermal diffusivity from the heat capacity and thermal conductivity of the soil. Hereby, the latter is calculated using Johansen technique, which is adjusted according to local mineralogy. Data were obtained using two thermocables and a neutron probe to establish some of the thermal and hydrologic properties, respectively. It may be concluded that the unusual soil properties significantly dampen the soil temperature profile thus affecting the permafrost table.

Key words: Schefferville, Québec, permafrost, thermal properties, moisture movement, iron oxides.

Résumé

L'auteur a effectué l'analyse du régime thermique d'une parcelle de pergélisol près de Schefferville, Québec. Cette parcelle expérimentale du lac Hématite est couverte d'une végétation de toundra alpine, et son sous-sol est gelé en permanence. La couche active, en raison de sa granulométrie grossière et de son contenu minéral, a des propriétés thermiques bien particulières. Les températures locales y sont beaucoup plus influencées par le déplacement des eaux que par le cycle diurne. En vue d'étudier le sol sous-jacent, l'auteur a relevé ses températures et ses teneurs en humidité. L'étude compare le régime thermique effectif avec l'équation de transmission calorique, et met en relief les anomalies de «diffusivité» thermique en se fondant sur la chaleur spécifique et a conductivité thermique du sol. On calcule cette dernière par la méthode de Johansen, modifiée en fonction du contenu minéral local. L'auteur a recueilli les données grâce à deux thermistances et à une sonde à neutrons, afin d'établir certaines des caractéristiques thermiques et hydrologiques du sol, respectivement. Il conclut que les propriétés inhabituelles de ce sol amortissent fortement le gradient thermique du sol et modifient en conséquence le niveau supérieur du pergélisol.

Mots-clés: Schefferville, Québec, pergélisol, propriétés thermiques, déplacement de l'humidité, oxydes de fer.

Introduction

While permafrost studies at Schefferville have been extensive (H.B. Granberg *et al.* 1983, 1984; R.K. Wright, 1979; F.H. Nicholson, 1978), they have mostly dealt with factors affecting permafrost morphology. These factors include thermal conductivity of the soil, vegetation, topography and snowcover thickness. Little attention, however, has been given to subsurface moisture and its role in heat redistribution. Subsurface moisture and its effects on the ground thermal regime were considered by P.J. Wieringa *et al.* (1970) for agricultural purposes. They found that in sufficiently permeable soil, near-surface layers are often cooled and deeper layers warmed upon the infiltration of rain- or irrigation water. It must be noted that the presence of water alters subsurface heat capacities as well as thermal conductivities, but can also cause heat redistribution by means of mass movement. Regarding these phenomena it is appropriate to study the coarse soil of Hematite Lake, even though iron oxides (40–50% by mass) increase the thermal conductivity of the mineral matter.

The experimental site, Hematite Lake, lies approximately 15 km NW of Schefferville P.Q. close to open mine pit FL. no. 3. While permafrost thickness reaches 76 m on some ridges (D.G. Ritter, 1984), it is absent in most valleys. The experimental site is underlain by 10–30 m of perennially frozen ground and has an active layer which extends to a depth of 3.0 m. The lower active layer is cooled strongly by the frozen layer so that the unfrozen ground tends to have a steep temperature gradient, which is little affected by diurnal air temperature variations. The local climate is similar to, though somewhat colder and windier than, that at Schefferville, which has a mean annual temperature of 269 K (D.F. Ritter, 1984). The subarctic location lies within the discontinuous permafrost zone. The site (elev. 685 m) has a slope of 11% and an extremely well-drained soil, which should be classified as a cryorthent according to the U.S. taxonomic soilsystem. Geologically, the area is part of the Labrador Trough and has a special lithology, which features a very high iron oxide content. The underlying Sokoman and Ruth formations consist of weakly metamorphosed Proterozoic, folded and faulted strata of ferruginous slate and leached iron compounds (R.K. Wright, 1979). Finally, vegetation should be considered scarce, ranging from none on bare frost scars to lichen alpine tundra (*Cladina stellaris, mitis; Stereocaulon spp.: Polytrichum spp.*)

Theory

Generally, the thermal regime of a soil can be expressed in terms of the thermal diffusivity, L, temperature, T, and depth, z:

$$\frac{\partial T}{\partial t} = L \cdot \frac{\partial^2 T}{\partial z^2} \qquad (1)$$

This equation, known as the heat conduction equation, applies to soils with constant thermal conductivity and thus to those without latent energy transfers and heat transfers involving mass movement. Consequently, L, the thermal diffusivity is based on heat transfer by conduction only. When soil contains water, phase changes and mass-heat redistribution take place and L varies accordingly. When heat transfer is augmented by such processes, L should not be considered a thermal diffusivity. Instead it should be thought of as a quasi thermal diffusivity (QTD), because few QTD values would be equal to L. Accordingly, it may be concluded theoretically that:

(a) If QTD < L, evaporation may be occurring in the soil,

(b) If QTD = L, heat transfer takes place by conduction,

(c) If QTD > L, then heat transfer, by either condensation or mass movement, occurs.

A time-series of temperatures from at least two depths would yield the thermal diffusivity, which is equal to the most common QTD value, provided that conduction is the most common type of heat transfer in the soil. The thermal diffusivity is then calculated for a particular soil at some average moisture content, which is considered to be an *in-situ* feature.

A second method to calculate the thermal diffusivity is the use of the ratio of conductivity, K, to the volumetric heat capacity, C:

$$L = (K/C) \qquad (2)$$

where

$$C = V_w C_w + V_s C_s + V_a C_a \qquad (3)$$

by fraction volume water, soil solids and air. Since the heat capacity of water is well-known and that of air negligibly small (P.J. Williams, 1982) and since heat capacity for soil solids can be indicated on the basis of mineralogical composition, it is possible to express C in terms of specific heats, c:

$$C = P_d \cdot (M_w c_w + M_s c_s + M_f c_f) \qquad (4)$$

where P_d is the bulk density and M_w, M_f and M_s refer to mass fractions water, hematite, and other soil minerals, respectively. It is necessary to obtain the thermal conductivity, K, of the soil in order to calculate L.

S.O. Johansen (1973, 1975) calculates soil thermal conductivity according to soil quartz content. Even though this method has been criticized for its rather large errors, it remains thus far the best available for calculating thermal conductivities of dry, coarse soils (O.T. Farouki, 1982). While Johansen's technique works relatively well for quartz-containing soils, the Hematite Lake cryorthent contains negligible amounts of quartz, but 46–62% by mass hematite. As a result of this unusual composition the Johansen equation for a dry soil,

$$K_d = 8.0^q \cdot 2.0^{1-q} \cdot K_a \qquad (5)$$

where K_d is the thermal conductivity at 0% water content and K_a that of air, has, instead of being in terms of quartz content, q, been based on f, the percentage hematite content by mass:

$$K_d = 11.3^f \cdot 2.0^{1-f} \cdot K_a \qquad (6)$$

The particle conductivity of hematite is 11.3 $Wm^{-1}K^{-1}$ (K.I. Horai, 1971), while that for other minerals, 2.0 $Wm^{-1}K^{-1}$ is unchanged. Johansen (1973, 1975) applies a correction for soils at intermediate levels of saturation, whereby the thermal conductivity,

$$K = K_d + Ke \cdot (K_s - K_d) \quad (7)$$

In this equation Ke is Kersten's number and K_s the soil thermal conductivity under saturated conditions. For coarse soils Kersten's number,

$$Ke = 0.7 \cdot \log (Sr) + 1.0 \quad (8)$$

where Sr, the degree of saturation can be written as follows:

$$Sr = \theta_w \cdot P_d / (P_w \cdot (1 - P_d / P_s)) = \theta_v / (P_w \cdot n) \quad (9)$$

Here, of course, porosity (n) is expressed in terms of bulk- (P_d) and particle densities (P_s):

$$n = (1 - P_d / P_s \quad (10)$$

and θ_w and θ_v are the gravimetric and volumetric water contents. The subscript w refers to water, so that:

$$K_s = K_d^{1-n} \cdot K_w^{n} \quad (11)$$

Thus while the first technique yields a QTD value, the second provides the thermal diffusivity. A comparison of the two, as suggested above should lead to the mode of heat transfer.

Experimental procedure

This investigation into the active layer thermal regime near Schefferville involved four types of measurement. Temperature measurements were made with thermistor cables, with ten thermistors spaced at 10 cm intervals on two cables (21C and 22C). These were inserted vertically into the ground, 40 m apart, on the gentle west-facing slope, The thermistor cables were left for 48 hours to establish a crude thermodynamic equilibrium with the soil. Temperatue data were obtained for a 30 day period in later summer. The measurements were taken manually at 30 minute intervals, so that 20 readings per half hour could be received. A second type of data gathering was the measurement of θ_v, the volumetric moisture content. Moisture contents were obtained at the same 10 cm intervals by lowering a fast-neutron source into the soil through an access tube. The moisture probe (model 503 Campbell Pacific Nuclear Corp.) provided daily volumetric moisture contents for sites 21C and 22C. Despite the absorption of neutrons by heavy iron minerals, as reported by R.K. Wright (1979), the results were within $\pm 3.2\%$ of water content tests involving the drying of samples according to soil science standard procedures. Neutron-probe data were needed to verify moisture movements and their correspondence to large quasi thermal diffusivities (QTD's).

Other measurements were the vertical extent of thaw, and particle and bulk densities. The vertical extent of thaw was monitored by using an auger in the neutron-probe access tubes. An estimate of the unfrozen layer thickness obtained this way probably involves an error of ± 4 cm, because of the nature of the permafrost 'table'. The objective was to observe changes in the level of the frozen zone in response to changes in the thermal gradient. Finally, standard soil science procedures were followed to determine particle and bulk densities of the soil. These densities were used in equation (10) to determine porosity, which was subsequently used in Johansen's method to calculate thermal conductivity.

Results

Common quasi thermal diffusivity values are 0.2 E−6 and 0.4 E−6 m^2s^{-1}, though a range from 0 to well over 1.0 E−4 m^2s^{-1} has been obtained from the heat conduction equation. Results from the second method, involving Johansen's technique, were not in agreement with those from the heat conduction equation. Moisture contents for both sites were approximately 7% on average, with a degree of saturation of ~0.15. As a result, calculated thermal conductivities are 0.66 and 0.70 $Wm^{-1}K^{-1}$ and calculated heat capacities are 0.71 and 0.78 $Jcm^{-3}K^{-1}$ for sites 21C and 22C, respectively. The thermal diffusivity, L, from equation (2) is approximately 9.0 E−7 m^2s^{-1}, which does not coincide with the statistical mode of QTD values. For complete results, refer to table 1.

The specific heats are based on the mass fraction of hematite, which has a specific heat, c_f, of 0.62 $Jg^{-1}K^{-1}$ (W.E. Forsythe, 1969; Y.S. Touloukian *et al.* 1970) and c_s, a specific heat common to most other soil minerals, of 0.80 $Jg^{-1}K^{-1}$ (P.J. Williams, 1982). Furthermore, the thermal conductivity of still water is 0.56 $Wm^{-1}K^{-1}$ according to P.J. Williams (1982). One must bear in mind, as is often explained (O.T. Farouki, 1982), that errors of as much as $\pm 20\%$ may accompany K calculated in this manner. The error associated with the derived thermal diffusivity could therefore be as large as ± 35–40%. Nevertheless, it is not large enough to account for the discrepancy between L and the mode of QTD's.

TABLE 1
Methodologically calculated variables.

		site 21C	site 22C	
P_d	dry bulk density (average)	1.22	1.31	gcm^{-3}
Ps	particle density (average)	3.16	3.20	gcm^{-3}
θ_v	volumetric water content (average)	0.090	0.095	gcm^{-3}
θ_w	gravimetric water content*	7.4	7.2	%
Sr	degree of saturation	0.147	0.160	
Ke	Kersten's number	0.417	0.443	
f	mass fraction Fe_2O_3**	0.54	0.48	
n	porosity	61.4	59.1	%
K_d	dry soil thermal conductivity	0.19	0.21	$Wm^{-1}K^{-1}$
K_s	saturated soil conductivity	1.31	1.32	$Wm^{-1}K^{-1}$
K	soil thermal conductivity	0.66	0.70	$Wm^{-1}K^{-1}$
c	specific heat	0.582	0.594	$Jg^{-1}K^{-1}$
C	volumetric heat capacity***	0.71	0.78	$Jcm^{-3}K^{-1}$
L	thermal diffusivity****	9.29 E−7	8.97 E−7	m^2s^{-1}

*based on θ_v (neutron-probe)
**based on acid-base Fe-extractions
***based on c
****based on K/C

Conclusion

The use of quasi thermal diffusivities (QTD's) make it possible to determine which heat transfer processes take place in the active layer. Mass-energy flows, especially, result in very high QTD's, which makes them easy to detect through this method. However, many absolute QTD's are smaller than L as determined using Johansen technique. Temperature fluctuations, which offset the water-water vapor phase equilibrium, occur constantly. Hence, many such small QTD's might be expected, however another factor must be

considered. Namely, QTD's are largely dependent on the magnitudes of both depth and temporal temperature gradients. For instance, a small $\partial T/\partial t$ or a large $\partial^2 T/\partial z^2$ will cause very small quasi thermal diffusivities, which may ultimately approach zero. The results for this method may not be typical, as the soil has a large porosity, which allows for a substantial impact of water as well as water vapor on its thermal regime. Secondly, caution in interpretation should be exercised, because of the unusually high Fe_2O_3 content, which has a very large thermal conductivity. The forementioned items should be of significant value to those intending to study changes in the top of permafrost.

Acknowledgments

Contributions to this paper have been made by Dr. M.W. Smith, Dr. P.J. Williams, Dr. J.P. Johnson and D. Riseborough of Carleton University, Ottawa, as well as D.T. Desrochers and Dr. H.B. Granberg of McGill University, C.R. Burn of the University of British Columbia and Dr. A.S. Judge of the Canadian Ministry of Energy, Mines and Resources. Great support in the way of technical supplies was received from Dr. Smith, and from the McGill Subarctic Research Station, Schefferville P.Q. This project was financially sponsored in part by the Department of Indian and Northern Affairs, while Dr. J.K. Torrance and Dr. J.P. Johnson of the Carleton University Geography Department commented on a draft of the paper.

References

Farouki, O.T. (1982) "Evaluaton of methods for calculating soil thermal conductivity" Cold Regions Research and Engineering Laboratory (CRREL) Report 82-8, 90 pp.

Forsythe, W.E. (1969) "Smithsonian physical tables" 9th revised edition, Washington D.C. 827 pp.

Granberg, H.B., Desrochers, D.T., Lewis, J.E., Wright, R.K., Houston, L. (1984) "Annotation, error analysis, and addenda to the Schefferville permafrost data file" Volume II-XV. Compiled at Geog. Dept. McGill University, Montreal.

Granberg, H.B., Lewis, J.E., Moore, T.R., Steer, P., Wright, R.K. (1983) "Schefferville permafrost research Volume I — summary, review, and recommendations and catalogue of available materials" Compiled at Geog. Dept. McGill University, Montreal.

Horai, K.I. (1971) "Thermal conductivity of minerals" Journal of Geophysical Research no. 76, pp. 1278-1308.

Johansen, S.O. (1973) "Beregningsmetode for varmeledningsevnen av fuktige og frosne jordarter" with english summary part II, Norwegian Geotechnical Science Journal, pp. 25-31.

Johansen, S.O. (1975) "Thermal conductivity of soil and rock" Frost I Jord no. 16, Oslo, pp. 13-21.

Nicholson, F.H. (1978) "Prediction of permafrost distribution for subarctic mining operations: Final report 1978" NRC, Canada, Special Project S-7308 pp. 34-36.

Oke, T.R. (1983) "Boundary layer climates" Methuen, New York, 372 pp.

Ritter, D.F. (1984) "Process geomorphology" WM.C. Brown Company Publishers, Dubuque, Iowa, 603 pp.

Touloukhian, Y.S., Powell, R.W., Hoy, C.Y., Klemens, P.G. (1970) "Thermophysical properties of matter" Volumes II, V and X, IFI/Plenum Data Corp., Washington.

Wieringa, P.J., Hagen, R.M., Nielsen, D.R. (1970). "Soil temperature profiles during infiltration and redistribution of cool and warm irrigation water" Journal of Water Resources Research Vol. 6 no. 1, pp. 230-238.

Williams, P.J. (1982) "The surface of the earth: an introduction to geotechnical science" Longman Inc., New York, 210 pp.

Wright, R.K. (1979) "The water balance of a lichen tundra underlain by permafrost" McGill University Ph.D. thesis, Montreal, 235 pp.

LE CLIMAT DES CAVERNES TSI-TCHÉ-HAN ET BEAR CAVE, NORD DU YUKON, CANADA

Pierre Thibaudeau

Département de géographie, Faculté des Arts, Université d'Ottawa, Ottawa, Ontario K1N 6N5

Niveau: Maîtrise

Résumé

Au cours de l'été 1985, les cavernes Tsi-tché-han et Bear Cave, situées à la latitude du cercle polaire arctique, ont été étudiées au point de vue climatique. Les températures et l'humidité relative de l'air furent enregistrées et les circulations de l'air ont été détectées. Les résultats ont permis de construire un modèle du comportement climatique des cavernes du Yukon septentrional durant la période estivale caractérisé par trois zones microclimatiques à l'intérieur des grottes. La première zone comprend un segment au 35 m depuis l'entrée, et est marquée par des températures positives, un influx de courants d'air chauds en provenance de l'extérieur et un taux d'humidité relative élevé. La deuxième zone est caractérisée par une température de l'air de 0°C et une humidité relative de 100%, qui résulte en la formation de glace et de cristaux de givre. Au-delà, dans la troisième zone, la température ambiante est de −2°C et l'air est sec et beaucoup plus stagnant, les seules circulations s'effectuant vers la sortie.

L'étude permet de confirmer la présence d'un pergélisol continu. Les concrétionnements importants impliquent des climats plus chauds dans le passé, possiblement au cours de différentes époques. Finalement, une tendance actuelle vers un réchauffement climatique régional pourrait provoquer le retrait du pergélisol et remettre en marche l'activité du concrétionnement.

Mots-clés: karst, microclimat, pergélisol, Yukon, concrétions.

Abstract

During the summer of 1985, the climatic aspects of Tsi-tché-han and Bear Cave caves, located on the Arctic circle, were studied. The temperatures and relative humidity were recorded and the circulation of air was determined. The results made it possible to propose a model of the climatic behavior of the northern Yukon caves during the summer period. This model identifies three microclimatic zones inside the caves. The first includes the segment between the entrance to a depth of 35 m, and is characterized by above-freezing temperatures, an influx of warm air flow coming from the outside and a high relative humidity. The second zone is characterized by an air temperature of 0°C and a relative humidity of 100%, resulting in the formation of ice and hoarfrost. Beyond, in the third zone, the ambiant

temperature is −2°C and the air is dry and much more stagnant, the only circulations flowing towards the exit.

The presence of continuous permafrost has been ascertained. The presence of concretions implies warmer climates in the past, possibly during different periods. Finally, a trend towards a regional warming could result in the retreat of permafrost and the reactivation of concretion formation.

Key words: Karst, microclimate, permafrost, Yukon, concretions.

Introduction

L'utilisation de concrétions pour l'étude des paléoclimats étant fréquente (Gascoyne *et al.*, 1983; Harmon *et al.*, 1977 et Henning *et al.*, 1983), il est nécessaire de comprendre les conditions climatiques dans lesquelles elles se forment. Le but de cet article est d'analyser des paramètres météorologiques de deux cavernes du nord du Yukon dans lesquelles se trouve une grande quantité de concrétions: les cavernes Bear Cave et Tsi-tché-han. L'emphase est mise sur les températures, l'humidité relative et la circulation de l'air. Les résultats sont un premier pas vers une meilleure compréhension du climat dans les cavernes du nord du Yukon et permettent de réfléchir sur les implications paléoclimatiques.

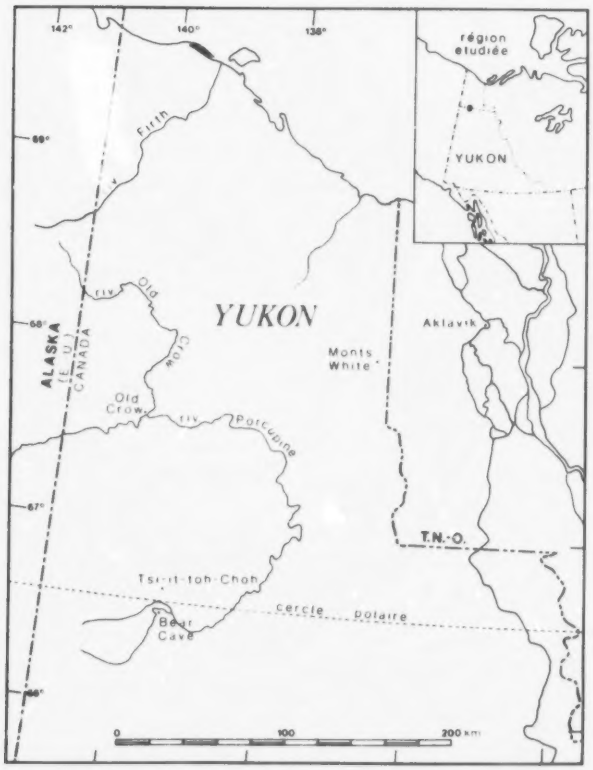


Figure 1. Localisation de la région d'étude.

La caverne Bear Cave: situation et description

La caverne Bear Cave se trouve au sein du massif du même nom, à la latitude du cercle polaire arctique, à 125 km au sud du village d'Old Crow, dans le nord du Yukon (Fig. 1). Elle fut visitée et décrite brièvement en 1953 par un géologue américain (Geist, 1953). La caverne constitue la plus longue cavité explorée dans le Yukon septentrional avec 220 m de passages cartographiés (Fig. 2). Elle s'ouvre à une altitude de 867 m par deux entrées (Fig. 3) situées près du sommet d'une falaise abrupte formant le versant sud-ouest du massif calcaire. La caverne domine de 400 m la vallée avoisinante. Elle est développée dans les formations Gossage et Ogilvie, de calcaire du Dévonien inférieur et moyen (Norris, 1985).

La caverne comprend trois salles de dimension importante au niveau supérieur et un niveau inférieur formé de passages d'une hauteur de 2 à 3 m. Ce niveau est accessible par la troisième salle et est également relié à la première salle par un conduit étroit. La caverne s'illustre par sa richesse en concrétions, notamment dans le niveau supérieur.

La caverne Tsi-tché-han: situation et description

La caverne Tsi-tché-han, dont le nom Kutchin signifie «trou dans la roche», a été nommée ainsi par Cinq-Mars et Lauriol (1985). Elle se trouve à l'extrémité nord du massif de Tsi-it-toh-Choh, lui-même situé à quelques kilomètres au nord du massif de Bear Cave. Ces deux croupes constituent le centre d'un anticlinal d'orientation nord-sud. Les formations calcaires dans lesquelles elles se trouvent représentent les plus anciennes roches exposées connues dans la partie septentrionale de la ceinture intérieure du Yukon (Gabrielse, 1975).

L'entrée de Tsi-tché-han (Fig. 4) se trouve à 30 m au-dessus d'un talweg, sur un versant régularisé d'orientation nord-sud (Fig. 5). Située à une altitude de 840 m, cette caverne s'est également formée suivant une structure horizontale. Suite à sa découverte, Cinq-Mars et Lauriol l'ont décrit comme suit: «La caverne comprend une salle de 18 m de long, 6 m de large et 2–3 m de hauteur. Deux galeries en partent: l'une, plutôt courte, est obstruée par un bouchon de glace, tandis que l'autre, longue de 10 m, large de 1 m et d'environ 2 m de hauteur, se termine par une petite chambre recouverte de cristaux de glace, suivie d'une étroiture. Au-delà de l'étroiture, la galerie semble reprendre du volume» (Cinq-Mars et Lauriol, 1985). Au cours de l'été 1985, on a réussi à pénétrer dans cette deuxième salle (Fig. 6). Cette dernière est d'une longueur de 10 m, d'une largeur de 4–5 m et d'une hauteur moyenne de 1m. Une cheminée de 4–5 m de hauteur dans chacune des salles suggère que la caverne fut façonnée par un écoulement sous pression des eaux.

Le climat du nord du Yukon

Le microclimat des cavernes est influencé directement par les conditions météorologiques de l'extérieur ainsi que par les variations saisonnières du climat. La région au sud d'Old Crow est caractérisée par un climat arctique très continental. La température moyenne annuelle est de −10°C. Les hivers y sont rigoureux et les étés courts, chauds et secs (température moyenne de janvier de −33°C et de juillet de 14°C). La brièveté de l'été est compensée par une forte durée

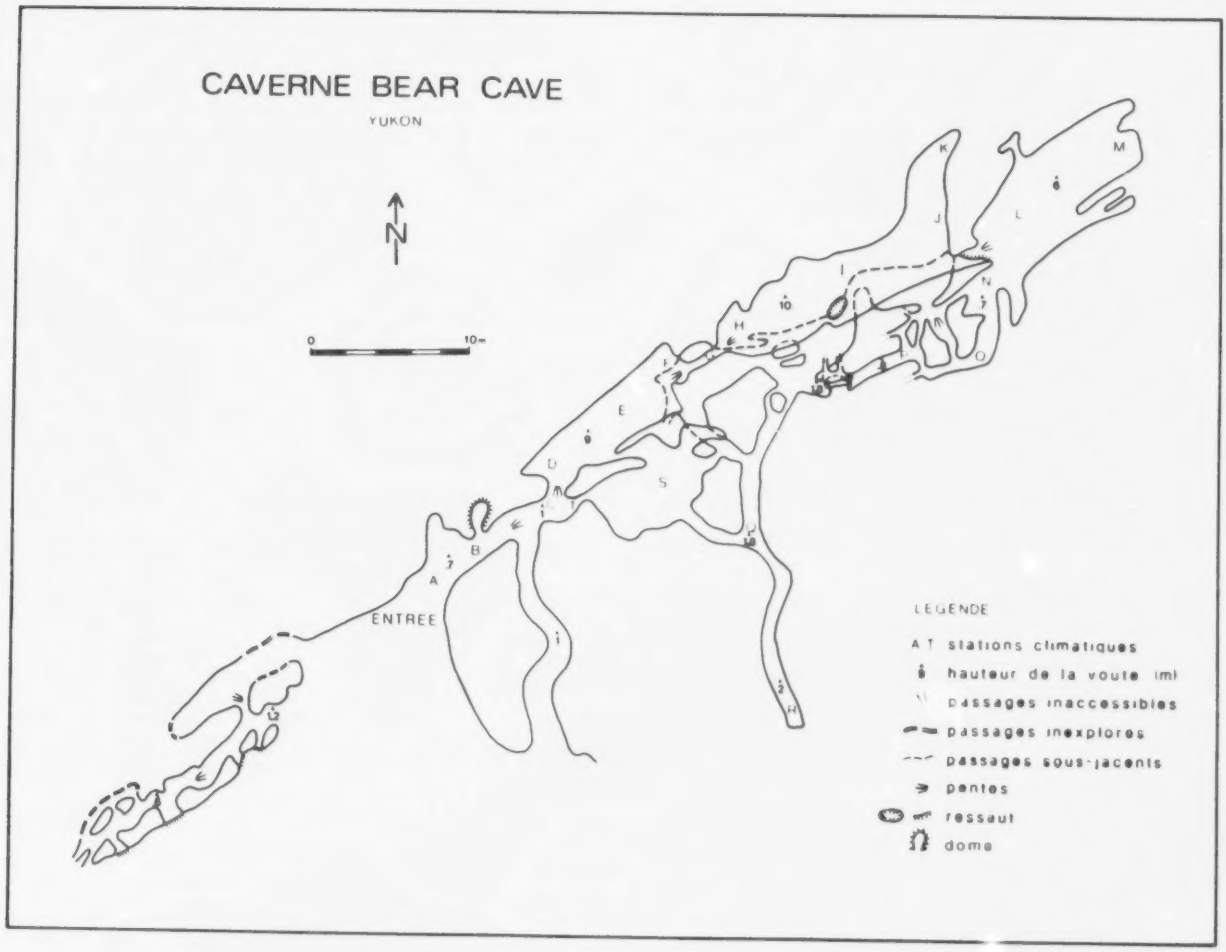


Figure 2. Plan topographique de la caverne Bear Cave.

d'ensoleillement en juin et en juillet, permettant à l'épinette noire de croître jusqu'à une altitude de 800 m, au-delà de laquelle la toundra alpine domine. Les précipitations, dont 50% parviennent sous forme de neige, sont de seulement 215 mm/an (Environnement Canada, 1982).

Méthodologie

Les mesures de la température de l'air ont été effectuées à l'aide d'un thermomètre à mercure dont la précision est de ±0.5°C. Dans la caverne Tsi-tché-han, les relevées de température de l'air ont été réalisés à 13 endroits et dans celle de Bear Cave, à 20 endroits.

L'humidité de l'air a été mesurée grâce à un psychromètre Model No. 566 de la firme Bendix, dont la précision est de ±0.5%. Ces mesures n'ont été effectuées que dans la caverne Tsi-tché-han, et aux mêmes endroits où les températures de l'air furent relevées.

La direction et la vélocité des courants d'air furent détectées à l'aide d'une poire à air en caoutchouc au bout de laquelle était enfoncée un tube de verre contenant une substance chimique dégageant une fumée de couleur blanche. Cette fumée, qui adopte une température et une densité identique à l'air ambiant, se stabilise une fois éjectée, et n'est déplacée que par les circulations d'air. Les mouvements de l'air ont été observés près des entrées, dans les salles et dans les fissures pouvant mener à d'autres passages. Ils furent également détectés à différentes hauteurs par endroits, c'est-à-dire au niveau du sol, à la mi-hauteur et près de la voûte. Leur vélocité a été calculée en m.sec.

Le microclimat de la caverne Tsi-tché-han

Les données climatiques de la caverne Tsi-tché-han ont été recueillies le 5 juillet 1985, alors que la température extérieure variait de 11°C à 16°C. Elles furent obtenues à l'intérieur de 13 «colonnes» d'air, chacune correspondant à un endroit défini dans la caverne depuis l'entrée vers le fond de la deuxième salle (Fig. 6). Les résultats (Tableau 1) permettent de définir trois zones climatiques bien différentes dans la caverne.

Températures et humidité relative de l'air

Les températures de l'air diminuent à mesure que l'on progresse dans la caverne. Près de l'entrée, la température

Figure 3. Entrée de la caverne Bear Cave, située à 867 m d'altitude.

Figure 4. Entrée de la caverne Tsi-tché-han, à une altitude de 840 m.

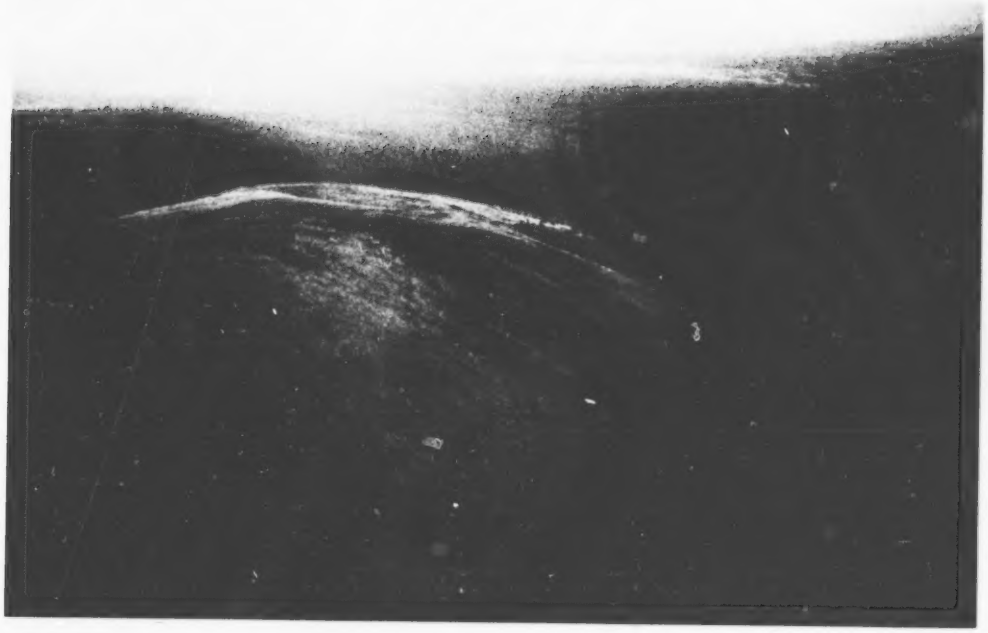


Figure 5. Extrémité nord du massif de Tsi-it-toh-Choh, où se situe la caverne Tsi-tché-han.

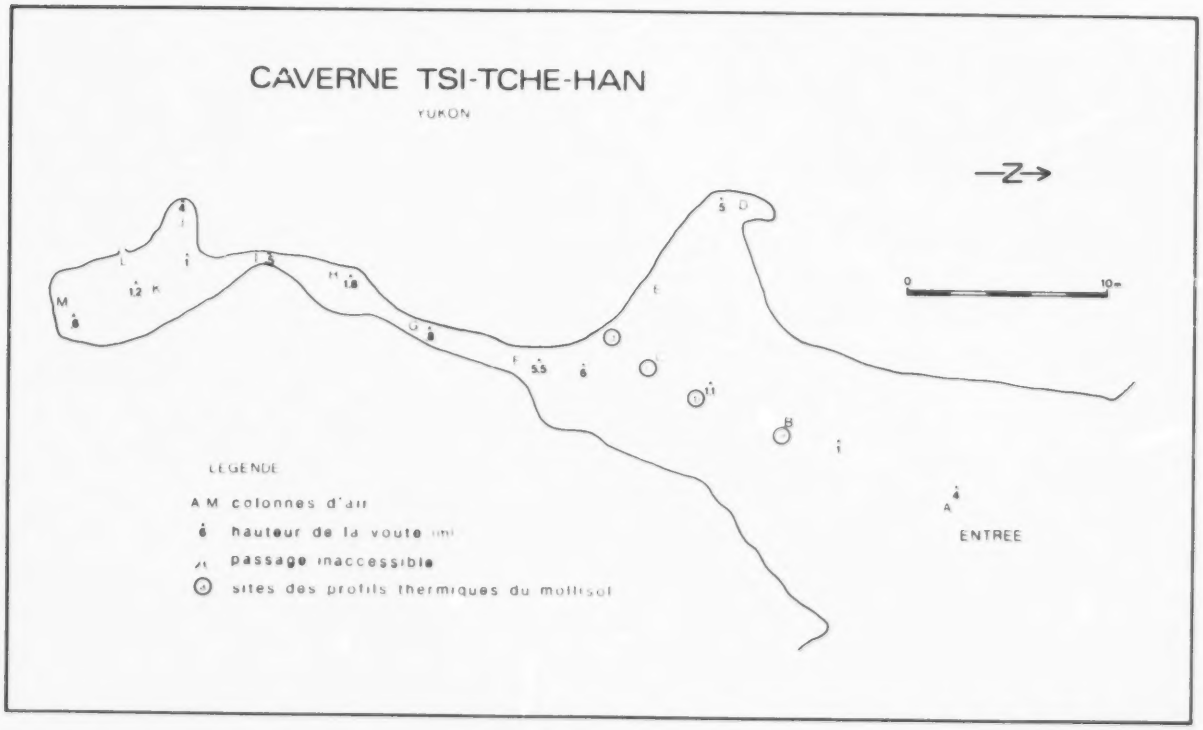


Figure 6. Plan topographique de la caverne Tsi-tché-han.

TABLEAU 1
Données climatiques dans la caverne Tsi-tché-han, relevées le 5 juillet 1985.

colonne	paramètre climatique	5 cm du sol	mi-hauteur	5 cm de la voûte	humidité (%)
A	température (°C) circulation d'air	9.0 vers ext.	8.9 ---	--- vers int.	84.7
B	température (°C) circulation d'air	4.5 vers ext.	8.2 ---	8.1 vers int.	83.0
C	température (°C) circulation d'air	2.8 vers ext.	5.0 ---	6.0 vers int.	86.0
D	température (°C) circulation d'air	1.0 vers ext.	1.0 ---	--- ---	85.9
E	température (°C) circulation d'air	1.0 ---	5.0 ---	5.5 ---	85.5
F	température (°C) circulation d'air	1.0 vers ext.	6.0 ---	7.1 vers int.	81.5
G	température (°C) circulation d'air	1.0 vers ext.	2.0 ---	4.8 vers int.	81.5
H	température (°C) circulation d'air	0.0 vers ext.	1.0 ---	2.0 vers int.	100.0
I	température (°C) circulation d'air	-1.5 vers ext.	-1.0 ---	-0.5 ---	---
J	température (°C) circulation d'air	-3.8 ---	-2.5 ---	-1.5 ---	66.0
K	température (°C) circulation d'air	-3.6 vers ext.	-0.5 ---	--- ---	64.2
L	température (°C) circulation d'air	-3.7 vers ext.	-2.1 ---	--- ---	64.0
M	température (°C) circulation d'air	-3.6 vers ext.	-0.5 ---	--- ---	63.2

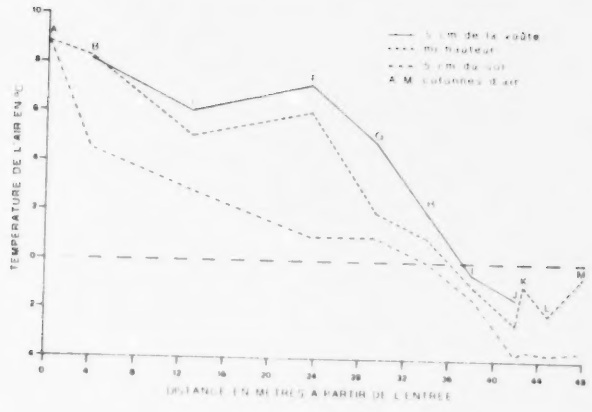


Figure 7. Température de l'air en fonction de la distance dans la caverne Tsi-tché-han.

moyenne de l'air est de 9°C tandis que dans la 2e salle, elle s'abaisse jusqu'à −3.8°C. Elle atteint le point de congélation dans la zone de la colonne H. Cette zone, formant une petite chambre, est caractérisée par des parois givrées.

Les changements de températures à différentes hauteurs dans les salles et dans les passages, soit à 5 cm du sol, à la mi-hauteur et à 5 cm de la voûte, sont représentés sur la Figure 7. Les températures sont plus élevées près de la voûte et sont à leur minimum près du sol. Le point de congélation, qui au sol survient à la colonne H, ne s'observe que quelques mètres plus loin près de la voûte, c'est-à-dire dans la région située entre les colonnes H et I.

Les températures à 5 cm du sol et à 5 cm de la voûte présentent des gradients thermiques de .263°C.m et .253°C.m respectivement de l'entrée jusqu'au fond de la grotte. D'autre part, les températures de l'air enregistrées à la mi-hauteur sont caractérisées par un gradient de .196°C.m. Une cheminée de 6 m de hauteur, située à la colonne F, emprisonne une poche d'air chaud, ce qui explique une augmentation de la température à cet endroit près de la voûte et à la mi-hauteur.

Des taux d'humidité relative variant de 81.5% à 86.0% furent enregistrés dans la première partie de la caverne, où les températures sont positives, soit à partir du point A au point G. Dans la zone du point H, l'humidité est de 100%. Au-delà, dans la deuxième salle, l'air est beaucoup plus sec, avec des taux fluctuant de 64.0% à 68.2%.

Circulation des courants d'air

L'air plus chaud provenant de l'extérieur en été pénètre dans la caverne en longeant la voûte. À une profondeur de 36 m, soit dans la zone de la colonne H, il se refroidie à une température de 0°C et change de direction en longeant cette fois le sol pour se diriger vers la sortie. Cet écoulement de l'air vers l'extérieur se produit lentement à une vitesse de 6 cm.sec dans le couloir et augmente à une vitesse de 50 cm.sec en arrivant dans la première salle. Cette augmentation de vélocité survient au moment où un autre écoulement, provenant cette fois du point D, vient s'ajouter au précédent.

Dans la deuxième salle, presqu'aucune circulation n'existe, exception faite d'écoulements provenant de minces passages inaccessibles et de fissures près des colonnes L et M. Ces derniers se dirigent à très faible vitesse vers l'extérieur de la salle en longeant le sol.

On distingue donc trois types de colonnes d'air au sein de la caverne Tsi-tché-han. Le premier ensemble, constitué des colonnes A à G, est caractérisé par des températures positives de l'air, une humidité relative située dans les 80% et une circulation d'air inversée, pénétrant dans la caverne près de la voûte et sortant de celle-ci près du sol. Le second type, représenté par la zone de la colonne H, possède des températures de l'air de 0°C et une humidité relative de 100%. Ces propriétés climatiques engendrent la formation de givre sur les parois, suite à la condensation de l'air, résultant en un changement de direction du sens d'écoulement. Finalement, le troisième groupe est formé des colonnes I à M, situées dans la deuxième salle. Celles-ci sont caractérisées par des températures négatives et des taux d'humidité relative dans les 60% tandis que la circulation d'air est quasi inexistante. Ces conditions font de la deuxième salle de la caverne un endroit très sec et froid.

Le microclimat de la caverne Bear Cave

Les relevés météorologiques de la caverne Bear Cave ont été effectués le 15 juillet 1985, journée caractérisée par des températures variant de 9°C à 16°C. Au moment de la prise des données, la température était de 12°C à l'extérieur de la caverne.

Étant donné la complexité du système souterrain formant la caverne et la dimension des salles et de certains conduits, les données climatiques de Bear Cave n'ont pu être enregistrées de façon aussi complète que celles de la caverne Tsi-tché-han, notamment en ce qui concerne les différentes hauteurs.

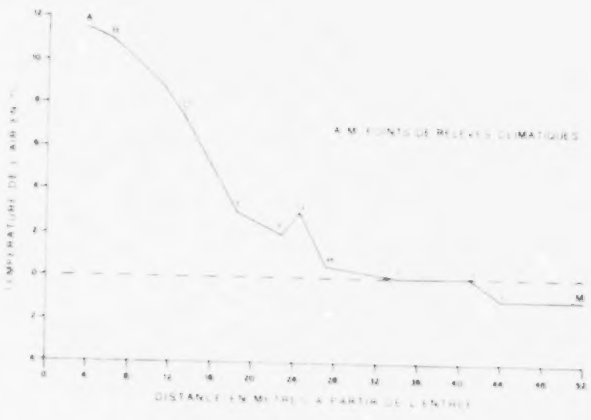


Figure 8. Température de l'air en fonction de la distance dans la caverne Bear Cave.

Figure 9. Formation de cristaux de givre sur les parois et de glace au sol dans la deuxième salle de la caverne Bear Cave.

Températures de l'air

Les températures de l'air régnant à l'intérieur de la caverne ont été mesurées à 20 endroits et les résultats sont divisés en deux parties; les points A à M, représentant le niveau supérieur de la caverne, et les points N à T, le niveau inférieur (Fig. 2).

Similaires à ceux de la caverne Tsi-tché-han, les résultats démontrent une diminution de la température de l'air depuis l'entrée vers la troisième salle, avec un gradient thermique de .212°C.m pour le niveau supérieur (Fig. 8). À l'entrée, la température est de 11.5°C près du plafond et de 10°C au niveau du sol. Celle-ci ne diminue que de peu jusqu'à l'entrée de la première salle, où elle est de 7.5°C au point D. Au fond de cette même salle, l'air se refroidit considérablement, pour atteindre 2°C. Tout comme dans la caverne Tsi-tché-han, une poche d'air chaud emprisonnée au point G, où un passage élevé s'observe, crée une irrégularité dans l'évolution des températures. À une profondeur de 30 m dans la caverne, soit au début de la deuxième salle, l'air atteint une température de 0°C, qui demeure constante partout dans cette salle. Encore une fois, ce point de transition entre une température positivie et négative se caractérise par la formation de givre sur les parois et d'un épais plancher de glace (Fig. 9). De plus, la dimension de la deuxième salle de la caverne Bear Cave est telle que des colonnes de glace de plusieurs m^3 ont également pu s'y former. Au-delà de cette «salle des glaces», la température de l'air se situe à −1°C.

Dans le niveau inférieur, la température de l'air semble constante, variant de −1°C à −2°C, et ce, indépendemment de la hauteur et de la distance par rapport à l'entrée.

Circulation des courants d'air

À quelques mètres à l'intérieur de la caverne, au point B, une forte aspiration de l'air chaud en provenance de l'extérieur et en direction de la première salle est évidente. La vélocité de la circulation d'air s'atténue sensiblement dans les salles mais un écoulement faible peut être détecté dans la première. Dans la deuxième salle et au-delà, l'air devient stagnant. Aucun courant d'air ne s'observe dans la troisième salle, sauf un écoulement faible vers le niveau inférieur (point N), où les températures sont sensiblement les mêmes. Par conséquent, l'écoulement de l'air n'apparaît pas de façon stratifiée. La circulation de l'air dans la galerie inférieure est difficilement perceptible mais a tendance à se diriger vers l'extérieur de la caverne. Finalement, un courant d'air froid venant du niveau inférieur s'écoule avec une vélocité importante depuis le point T, en longeant le sol vers l'extérieur de la grotte par l'entremise du couloir menant à l'entrée secondaire.

Modèle de la circulation générale de l'air dans les cavernes

Une analyse et une comparaison des résultats obtenus dans les cavernes Tsi-tché-han et Bear Cave soulignent la grande

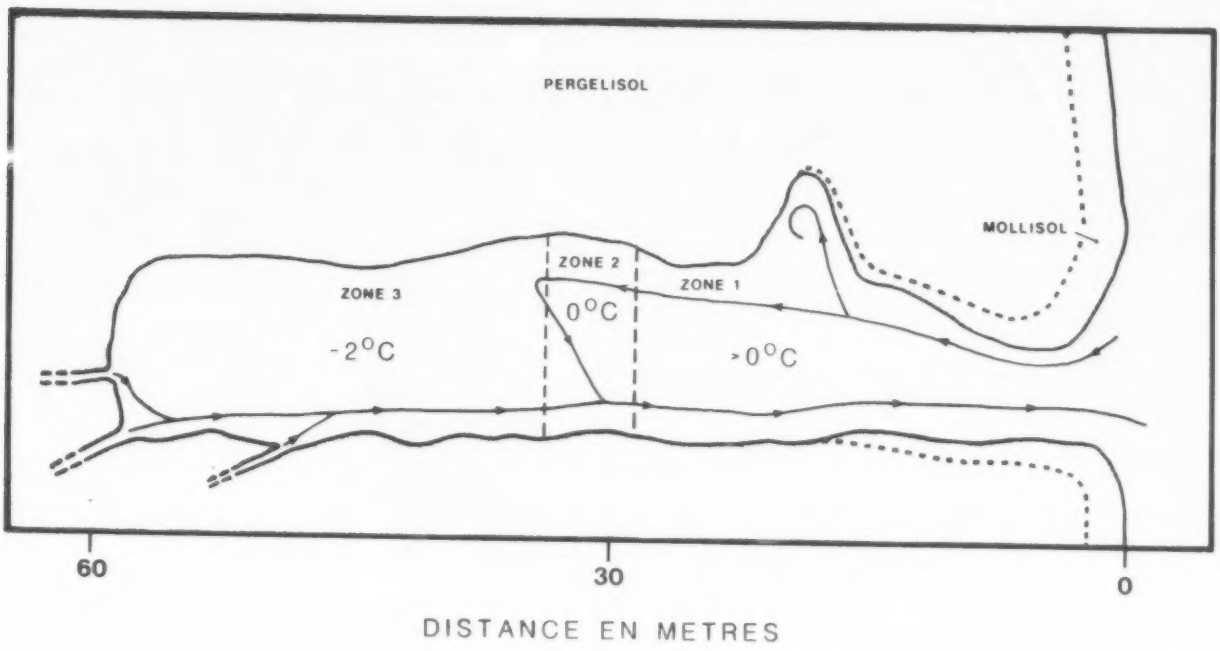


Figure 10. Modèle du comportement microclimatique dans les cavernes du nord du Yukon durant la période estivale.

similitude des propriétés thermiques des deux systèmes de cavernes ce qui permet de proposer un modèle du comportement microclimatique de ces cavités pour la période estivale (Fig. 10).

Durant l'été, l'air plus chaud de l'extérieur pénètre dans la caverne en longeant la voûte. La température des parois rocheuses provoque le refroidissement de l'air en fonction de la distance en profondeur, suivant un gradient moyen de .231°C.m. Après un parcours de 30–35 m sous terre, cet air atteint le point de congélation. Il y a du même coup perte d'humidité résultant en une condensation de l'air et ainsi formation de givre sur les parois et d'un plancher de glace. Une boîte de pellicule photographique laissée dans la deuxième salle de la caverne Bear Cave par Geist en 1953 se trouve présentement enfouie de plusieurs centimètres dans un plancher de glace, témoignant ainsi de l'activité actuelle de ce processus. Une fois l'air refroidie au point de congélation et dépourvu de son humidité, un changement de direction du sens d'écoulement se produit. L'air s'écoule vers l'extérieur en longeant cette fois le sol et en se réchauffant suite à l'influence des parois. Le rôle que joue le niveau de la mi-hauteur dans les passages souterrains en tant que zone de transition entre les températures plus chaudes près de la voûte et celles plus froides au niveau du sol s'avère important. Comme le témoignent les gradients thermiques, les températures sont plus constantes à la mi-hauteur.

À une profondeur au-delà de 35 m les températures demeurent inférieures à 0°C à l'année longue. La circulation d'air durant l'été est presque inexistante, exception faite de faibles écoulements d'air froids longeant le sol vers l'extérieur. Ces derniers proviennent des fissures dans la roche. Cette absence quasi totale de circulation d'air s'avère important dans le maintien des températures négatives, empêchant tout échange énergétique avec l'air pénétrant dans la caverne depuis l'extérieur. Un air extrêment sec en résulte.

Les mêmes caractéristiques s'observe dans la caverne Castleguard, située dans un environnement alpin au coeur des montagnes Rocheuses. Elle possède des formations de glace similaires, quoique beaucoup plus complexes, également provoquées par la circulation de l'air (Atkinson *et al.*, 1983). Ces formations de glace au sein des cavernes témoignent ainsi de l'échange énergétique existant entre l'extérieur et l'intérieur d'une cavité souterraine par l'intermédiaire des courants d'air.

Implications de la circulation atmosphérique sur les processus actuels des cavernes

Le microclimat d'une caverne est influencé en partie par les températures de la roche régnant à l'intérieur de celle-ci. Cependant, la circulation atmosphérique et les conditions climatiques de l'extérieur jouent un rôle primordial dans leur évolution.

Dans le nord du Yukon, une influence directe du réchauffement atmosphérique en période estivale se traduit par la formation d'un mollisol dans les premiers 20 m des cavernes étudiées. Des profils thermiques du sol (Fig. 11) ont été effectués dans la première salle de la caverne Tsi-tché-han (Fig. 6), à l'aide d'un thermomètre Model 425 de la firme YSI rattaché à une sonde en métal que l'on enfonce dans le sol, constitué principalement de loess. L'instrument offre une précision de $\pm$ 0.5°C. Le premier sondage, effectué dans la caverne à 10 m de l'entrée, indique une température de la surface du sol de 4°C tandis que le pergélisol se trouve à 20 cm de profondeur. La surface du sol se refroidit

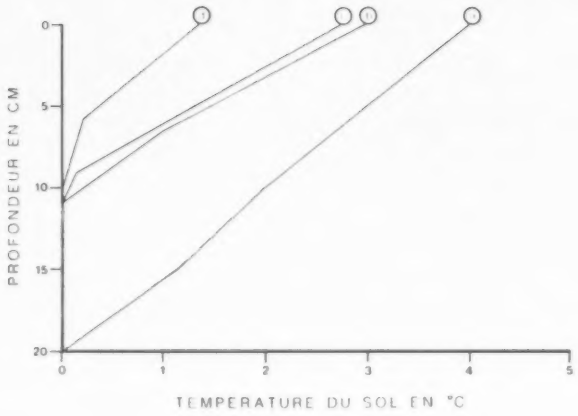


Figure 11. Profils thermiques du mollisol dans la première salle de la caverne Tsi-tché-han (voir figure 6 pour la localisation des sites où les profils furent effectués).

progressivement et le pergélisol se retrouve de plus en plus près de la surface à mesure que l'on pénètre dans la caverne. Au fond de la première salle, à 20 m de l'entrée, la surface du sol a une température de 1.4°C et le pergélisol est à 10 cm de profondeur. Le sol du couloir menant vers le fond de la caverne est couvert pour sa part d'un plancher de glace. Bref, la couche active ne se forme que dans la première salle, au-delà de laquelle, le sol très sec demeure gelé en permanence jusqu'en surface. Ce processus saisonnier doit son existence aux variations climatiques de l'extérieur de même qu'à la morphogénèse même de la caverne, dont l'entrée s'est vraisemblablement formée suite au recul du versant.

Le maintien de températures négatives en profondeur dans les cavernes durant toute l'année, combiné à l'assèchement de celles-ci, sont des facteurs qui réduisent considérablement la gélifraction. Ceci permet la conservation des concrétions et évite l'enfouissement des parterres sous des blocs détachés des parois.

La sècheresse du climat de l'extérieur, combiné au déficit hydrique important et au nombre faible de cycles gel/dégel réduit également l'effet de la gélifraction même sur les roches exposées aux éléments de la nature. Cependant, dans cette région épargnée par les glaciations du Quaternaire (Prest, 1970), le temps représente un facteur important dans l'évolution du paysage où tout semble se produire au ralenti. Des blocs de roche observés près de l'entrée de la caverne Tsi-tché-han, vraisemblablement détachés sous l'effet de la gélifraction, témoigne de l'activité lente mais constante de ce processus qui contribue grandement à l'agrandissement de l'entrée de la caverne (Schroeder 1980).

La formation de glace et de givre dans les cavernes Tsi-tché-han et Bear Cave sont le résultat des conditions météorologiques existant dans celles-ci. Le microclimat dans les cavernes étant directement relié par contre au climat extérieur, il est essentiel de souligner l'influence de ce dernier face à la formation de glace et de givre.

En dépit de la présence actuelle d'un pergélisol continu, les cavernes possèdent des concrétions dont on ne retrouve l'équivalent que plus loin au sud. Leur présence implique au moment de leur formation l'absence d'un pergélisol continu, et des températures positives dans les cavernes, soit quelques degrés supérieurs à aujourd'hui. Le concrétionnement est indicateur d'une forte activité chimique des eaux d'infiltration durant possiblement plusieurs périodes du passé. L'installation du pergélisol aurait mis un terme à la percolation des eaux dans le sol, mettant ainsi fin à l'activité des cavernes.

Conclusion

Les cavernes Tsi-tché-han et Bear Cave constituent les deux plus grandes cavités souterraines étudiées dans le nord du Yukon. Une première étude de leur microclimat a permis d'en relever quelques caractéristiques. Ces cavernes apparaissent actuellement sous forme relique, perchées près du sommet des massifs calcaires. Elles furent cependant, à une époque antérieure, aussi active que le sont aujourd'hui d'autres phénomènes karstiques présents dans le fond des vallées (Cinq-Mars, 1982; Roberge *et al.* 1986). Un réchauffement climatique régional aurait comme effet, dans le futur, de modifier le microclimat actuel des cavernes Tsi-tché-han et Bear Cave et peut être même de remettre en marche une autre période de concrétionnement. Ce phénomène pourrait être provoqué par l'intervention indirecte de l'homme. En effet, d'après Kellogg (1984), il est possible que l'augmentation du CO_2 dans l'atmosphère suite aux activités humaines provoque au siècle suivant des perturbations climatiques considérables. Un accroissement des précipitations en hiver, à des étés plus sec et un retrait graduel du pergélisol.

Ce sont là trois des conditions climatiques qui, dans le passé, ont caractérisées certainement les périodes durant lesquelles le concrétionnement s'est produit.

Remerciements

Cet article présente les résultats d'une partie des recherches entreprises par l'auteur dans le cadre d'une thèse de maîtrise, dirigée par le Prof. Bernard Lauriol. Je remercie le Prof. Lauriol pour son aide et ses conseils précieux ainsi que pour sa révision du texte. Le séjour sur le terrain a été rendu possible grâce à l'appui logistique du projet du plateau continental polaire et M. Jacques Cinq-Mars (Musée national de l'homme, Ottawa). L'assistance sur le terrain de Jean Roberge de l'université Laval fut aussi très appréciée. La recherche a été financée par une bourse du Groupe de recherches nordiques de l'université d'Ottawa, accordée à l'auteur, de même que par une subvention du Conseil de recherche en sciences naturelles et en génie, au Prof. Lauriol.

References

Atkinson, T.C., Smart, P.L., and Wigley, T.M.L. 1983. Climate and Natural Radon Levels in Castleguard Cave, Columbia Icefields, Alberta, Canada. *in*: Castleguard Cave and Karst, Columbia Icefields Area, Rocky Mountains of Canada: A Symposium. Edited by D.C. Ford, Arctic and Alpine Research, 15(4):487-502.

Cinq-Mars, J. 1982. Les grottes du Poisson-Bleu. Géo. 11(1):19-21.

Cinq-Mars, J., et Lauriol, B. 1985. Le karst de Tsi-it-toh-Choh: Notes préliminaires sur quelques phénomènes karstiques du Yukon septentrional, Canada. Annales de la Société Géologique de Belgique, Tome 108:185-195.

Environnement Canada. 1982. Normales climatiques au Canada, 1951-1980. Températures et précipitations. Le nord — T.Y. et T.N.-O. Publication du programme Climatologique Canadien, Ottawa, 55 p.

Gabrielse, H. 1975. Canada — Cordilleran Region, Interior and Western Belts, *in*: "The Encyclopedia of World Regional Geology Part 1: Western Hemisphere". Edited by R.W. Fairbridge, Dowden, Hutchison & Ross, Inc., p. 179–187.

Gascoyne M., Ford, D.C., and Schwarcz, H.P. 1983. Rates of Cave and Landform Development in the Yorkshire Dales from Speleothem Age Data. Earth Surface and Landforms, 8:557–568.

Geist, O.W. 1953. Scientific Investigations in the Old Crow and Porcupine River Region of Alaska and Yukon Territory. Ms., 108 p., University of Alaska, Fairbanks, Alaska.

Harmon, R.G., Schwarcz, H.P., and Ford, D.C. 1977. Interglacial Chronology of the Rocky and MacKenzie Mountains Based Upon $^{230}Th/^{234}U$ Dating of Calcite Speleothems. Canadian Journal of Earth Sciences, 14:2543–2552.

Henning, G., Grun, R., and Brunnacker, K. 1983. Speleothems, Travertines and Paleoclimates. Quaternary Research, 20:1–29.

Kellogg, W.W. 1984. Possible Effects of a Global Warming on Arctic Sea Ice, Precipitation, and Carbon Balance, *in*: The Potential Effects of Carbon Dioxide Induced Climatic Changes in Alaska, 1984. The Proceedings of a Conference, Edited by Jennifer M. McBeath, School of Agriculture and Land Resources Management, University of Alaska, Fairbanks, Alaska, p. 59–66.

Norris, A.W. 1985. Stratigraphy of Devonian Cutcrop Belts in Northern Yukon Territory and Northwestern District of Mackenzie (Operation Porcupine Area). Geological Survey of Canada, Memoir 410, 81 p.

Prest, V.P. 1970. Quaternary Geology of Canada, *in*: "Geology and Economic Minerals of Canada", Geological Survey of Canada, p. 676–764.

Roberge, J., Lauriol, B., Thibaudeau, P., et Cinq-Mars, J. 1986. Caractère des karsts arctiques du Yukon septentrional. Texte présenté au congrès international de spéléologie, Barcelona, Espagne, juillet 1986, 7 p.

Schroeder, J. 1980. Le développement des grottes dans la région du premier canyon de la rivière Nahanni-sud, T.N.-O. Thèse de doctorat, Université d'Ottawa, 302 p.

AN ASSESSMENT OF AERIAL PHOTOGRAPHS AS A SOURCE FOR SURROGATE FIELD MEASUREMENTS OF ICE JAMS IN THE LIARD/MACKENZIE RIVERS, N.W.T.

Shelley Watson

Watershed Ecosystems Program, Trent University, Peterborough, Ontario K9J 7B8

Level: Master's

Abstract

Stereoscopic aerial photographs of six ice jams in the Liard/Mackenzie river confluence (1974–1980) are analysed to assess their applicability as a source for surrogate water level and ice jam field measurements. Considering the many dangers inherent in collecting field data on an ice jam, the development of a stereo-photogrammetric technique for obtaining ice jam measurements becomes an attractive and valuable exercise.

Using a Zeiss G-2 Stereocord, surrogate elevation measurements of the ice jam's longitudinal water surface profile are established. The mean of elevation data points within a 2 cm^2 grid (400 m^2 of river surface) from each stereoscopic model provides the best estimate of the ice jam water level. Elevations are within an average accuracy of ± 0.32 m. The estimated profile is used as replacement field data to describe the configuration of the ice jam accumulation, the change in water level and associated backwater effects. The advantages and limitations of the proposed technique are also discussed.

Surrogate field measurements of the ice jam and corresponding water levels are obtained safely and economically. They provide a six-year historical data base of ice jam and water level measurements of the Liard/Mackenzie river confluence, N.W.T. Ice jam analysis using aerial photographs represents a strong input to ice jam research.

Key words: Ice jams, aerial photographs, river ice breakup, Liard/Mackenzie rivers, N.W.T.

Résumé

L'auteur analyse des couples stéréoscopiques de photographies aériennes de six embâcles formés de 1976 à 1980 au confluent de la Liard avec le Mackenzie, afin d'évaluer l'utilisation éventuelle de ces couples comme indicateur supplétif du niveau des eaux et pour la mesure de l'embâcle. En raison des nombreux risques d'accidents quand on recueille sur place les données sur les embâcles, la mise au point d'une méthode stéréophotogrammétrique pour leur mesure constitue un objectif utile et intéressant.

On effectue les mesures supplétives des cotes de hauteur de la surface de l'embâcle au long de son profil longitudinal, à l'aide du Stereocord Zeiss G-2. La moyenne de 25 et 50% des cotes les plus basses de chaque modèle stéréoscopique fournit la meilleure estimation du niveau de l'eau sous l'embâcle.

On utilise le profil externe suppléant les données relevées sur place afin de décrire la forme de l'embâcle, la modification du niveau de l'eau et les effets de son refluement vers l'amont.

La mesure supplétive des embâcles et des niveaux correspondants des eaux constitue une méthode sécuritaire et économique. Elle a fourni une basse de données chronologiques couvrant six ans au sujet des embâcles et des niveaux des eaux au confluent de la Liard et du Mackenzie. L'analyse des embâcles sur photographies aériennes fait un apport valable à la recherche sur les embâcles.

Mots-clés: Embâcle, photographies aériennes, débâcle, rivière Liard et fleuve Mackenzie, T.N.-O.

Introduction

Of all the subjects within the general domain of river ice, ice jams are probably the least understood and most difficult formation to measure. The main focus of early quantitative ice jam research has been theoretical dynamics, hydraulics

and predictive modelling of ice jam phenomena (e.g., Pariset *et al.*, 1966; Michel, 1971; Chizov, 1974; Uzuner and Kennedy, 1976). More recently, authors have expressed the need for more field data in ice jam analyses to make possible the testing of existing theories and models (Beltaos, 1983; Michel, 1983; Gerard, 1984). Accurate ice and water level measurements are important for the success of this research. However, there are several limitations of the present methods for collecting water level data during ice break-up and jamming.

Stage observations at hydrometric gauging stations serve only as initial data for the analysis of river ice break-up and jam formation. In large northern rivers where ice accumulations can be of great magnitude (e.g., Prowse, 1984, 1986a), there is a high risk of the ice moving and destroying the stage recording orifice. In remote areas, the water gauging stations may be too sparse for the effective study of ice jam water level stages. Hydrometric station records provide useful, though incomplete information (Beltaos, 1984a). Rapidly changing ice formations and water levels create numerous, closely-spaced peaks on the water level records, making it difficult to determine an accurate representation of the water level.

The collection of a series of field measurements during break-up and jamming events would provide the much-needed field input to ice jam research. However, it is a dangerous and costly procedure. The unpredictable movements of the ice surface make walking on it unsafe. The use of aircraft can reduce the accessibility and safety problems, although an extensive aerial survey (over a number of years) would be very costly.

At the present time, ice jam water levels are measured according to a technique outlined by Gerard (1975) (e.g., Doyle and Andres, 1978; Beltaos, 1983; Prowse, 1984, 1986a). The technique involves photographing jam water levels near identifiable objects along the river bank from low-flying aircraft or from ground access points. Later, open water surveys are performed to locate and determine the elevation of the photographed water levels, relative to the open water level. One problem with this method is that there is an almost complete absence of open water in the jam when water levels begin to recede (Doyle and Andres, 1978). The documentation of water levels becomes an impossible task.

Instantaneous measurement of ice jam water levels can produce very irregular results (Calkins, 1983). The dynamic movement and stoppage of the ice cover during break-up and jamming creates transient surges in the river. Instantaneous readings taken by observers could reflect a surge condition if precautions are not taken to ensure the cover is in a stationary position.

In view of these limitations, the development of a safe, economic and accurate method of collecting ice jam field measurements is needed. Aerial photographs may be the answer. Vertical aerial photographs provide a permanent record of river ice and channel conditions at the time of photo acquisition. A three-dimensional model of the terrain can be generated by means of photo control and the proper rectification of stereopairs on a stereophotogrammetric instrument. Airphotos can then become a data base for surrogate field measurements which may be analysed, used to verify existing measurements or to test developed theories and models.

At the present time, the quantitative potential of airphotos for studying ice jams has been utilized by only a few North American researchers (Sherstone, 1973; MacKay *et al.*, 1974). Most quantitative ice jam research, using aerial photographs, has been undertaken by research scientists of the State Hydrologic Institute in the U.S.S.R. (Kudritskii *et al.*, 1956; Molchanov and Vlasov, 1974; Molchanov, 1975; Vlasov, 1977).

Vlasov (1977) describes several experimental aerial investigations of ice jams which were performed on some northern rivers of the U.S.S.R. in 1971 and 1972. Aerial photo surveys on scales from 1:10 000 to 1:25 000 were made to determine the quantitative and qualitative morphological characteristics of ice jams and flood zones. Ice jam water levels were determined photogrammetrically and stereophotogrammetrically with a standard error of ± 0.40 m. The accuracy in the present field method of collecting ice jam water levels (Gerard, 1975) ranges between ± 0.30 m to ± 0.80 m (e.g., Doyle and Andres, 1978). Therefore, accuracy of the airphoto method is considered quite adequate for the description of ice jam water levels. However, the advantages and limitations of using such a technique are not discussed.

The purpose of this study is to assess the applicability of aerial photogaphs as a source of surrogate field data of water levels and ice accumulations during spring break-up in the Liard/Mackenzie rivers from 1974–1980. This is achieved by establishing surrogate elevation measurements of the ice jam longitudinal water surface profile from aerial photographs, and comparing them with actual field data of water levels taken at the time of photo acquisition. Interpretation of the surrogate field data illustrates the advantages and limitations of the technique for relating the configuration of the ice and water surface to the river regime. It also provides six years of historical ice jam data for the Liard/Mackenzie river confluence, N.W.T.

Background

The Importance of Studying Ice Jam Longitudinal Water Surface Profiles

Maximum water levels produced by ice jams depend strongly on the ice cover configuration. Ice jams change the longitudinal water surface profile by producing sharp water fluctuations due to the accumulation of ice in the river channel.

Once ice is stopped at a location, the jam thickens rapidly, primarily by ice blocks turning under existing surface ice. This causes rapid constriction of the channel and subsequent rising of the upstream flow. The ice jam's aggregate thickness (many metres) as well as the hydraulic resistance of their undersides also cause high upstream water levels. The increase in the flow resistance on the ice jam length is larger, the greater the amount of ice, the higher its strength and the greater the velocities at which it approaches the place of ice jamming (Shulyakovskii, 1963).

Two types of ice jams are known to form in northern rivers. They are: floating (simple) or grounded (dry) ice jams. Floating ice jams are characterized by an accumulation of floating ice floes on the water surface with water moving

under the ice cover. The maximum water level attained through the jam is governed by its thickness and resistance to flow under the ice.

Grounded ice jams are characterized by an accumulation of ice floes which block the whole flow section of the river down to its bed. Water flows by infiltration through the porous ice mass. The maximum water level is governed by the resistance to flow through the accumulation. It may be that this type of ice jam causes the highest water levels, yet it is the one about which the least is known. Both floating and grounded ice accumulations can exist within the same jam. Grounding usually occurs at the toe and shallow areas.

Ice jams are "unsteady" phenomena because of the transient nature of their initiation, formation and release. Nonetheless, under certain circumstances, a jam may attain a "steady-state" condition. Theoretical research has concentrated on modelling and predicting these floating equilibrium jams (Berdennikov, 1964; Pariset *et al.*, 1966; Michel, 1971; Uzuner and Kennedy, 1976; Beltaos, 1983b; Calkins, 1983; Beltaos and Wong, 1984). They have practical merit since it is believed that the highest water stages occur when a jam has attained equilibrium.

Figure 1 is a schematic illustration of an equilibrium jam. It is assumed to be initiated at the edge of an undisturbed ice sheet and in a steady state condition. Beltaos (1983) describes the three distinct regions as:

1. *The Upstream Transition* — the ice area below the head of the jam where the thickness of the ice increases and approaches an asymptotic value. The flow, under the jam, varies gradually through this region. The longitudinal profile shows a slight decrease in backwater as the head of the jam is approached.

2. *The Equilibrium Thickness Reach* — the central portion of an ice jam where its thickness is relatively uniform. This thickness is equal to the asymptotic value previously mentioned and is termed the "equilibrium thickness" (Uzuner and Kennedy, 1976). The flow under the jam is uniform with the water surface slope equal to the channel bed slope. This concept applies to prismatic channels but may be extrapolated to natural streams by replacing the channel bed slope with the open-water surface slope. These conditions are assumed to be true only if the ice jam is free-floating and there is uniform flow underneath. Moreover, if a jam is too short (less than ten stream widths), the equilibrium thickness region may not form and uniform flow will not occur (Calkins, 1983). Surrogate field measurements of ice and water levels in the equilibrium section may provide the needed information to test the existing theory.

3. *The Downstream Transition* — (Toe region) — the area below the equilibrium reach where the water surface profile steepens progressively to meet the relatively low water stage that exists at the toe of the jam. The gradient of the water

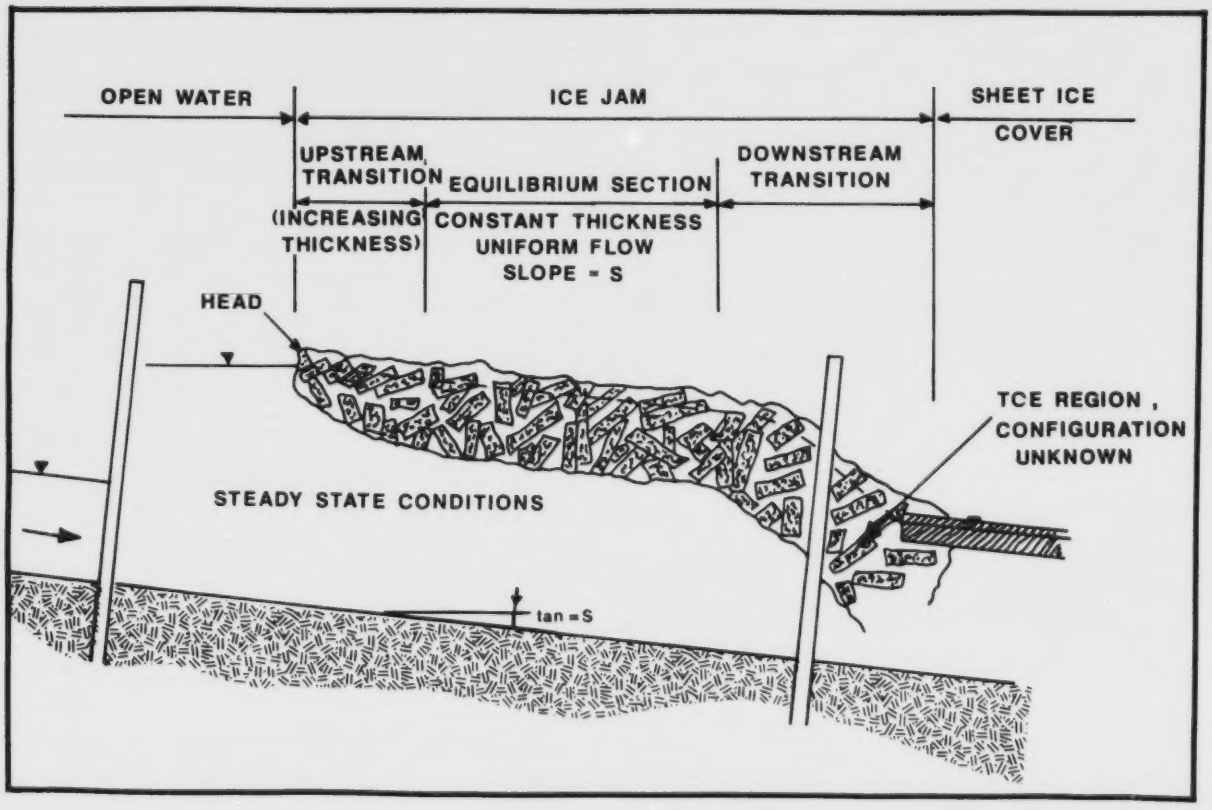


Figure 1. Schematic illustration of an ice jam. Source: Beltaos (1983).

TABLE 1
Ice jam slopes (m/m)

AUTHOR	RIVER	SLOPES		
		TOE REGION m/m	EQUILIBRIUM m/m	OPEN WATER EQUILIBRIUM m/m
Andres & Doyle(1984)	Athabasca(1977)	0.0024	0.00075	~0.0007
"	" (1978)	0.012		
"	" (1979)	0.0036		
Beltaos (1981)	Thames (1981)	0.0040	0.00026	~0.00027

5-30 times open water slope

surface many times surpasses the gradient of the open channel where ice accumulations have a considerable thickness. Flow hydraulics in this region are non-uniform. Major unknown variables in the mathematical modelling of jam formation are the flow and stability conditions at the ice jam toe, particularly when the toe is grounded (Joliffe and Gerard, 1982). Measurement of ice and water levels in this region provide insight into jam configuration and backwater effects.

Equilibrium ice jams and their characteristic longitudinal water surface profiles do not always occur in nature. Many researchers investigating river ice break-up in various parts of the world have illustrated a variety of ice jam water surface profile configurations (Chizhov, 1975a,b; Wuebben and Stewart, 1978; Doyle and Andres, 1978, 1979; Beltaos, 1981; Andres and Rickert, 1984). Several features common to all profiles include:

- position of major and minor jams,
- sharp increase in stage at the toe of the major and minor jams,
- slightly increased stage through the body of the jams with some variability,
- decrease in backwater as the head of the jam is approached.

Table 1 provides the values of the water level slopes through the toe and equilibrium sections of ice jams in the Athabasca and Thames rivers (Beltaos, 1981; Andres and Rickert, 1984; Doyle and Andres 1978, 1979). Toe slopes appear to be 2 to 30 times greater than the open-waer slopes.

In several examples where the water surface has no adverse gradient or marked change in slope, the empirical points were generalized as a smooth curve. Nonetheless, distinct depressions or peaks in the profiles were not adequately explained. Little was indicated about their relationship to the ice accumulations or open-water profile.

Since an ice jam causes significant local deviations on the water level profile with very large gradients at the toe, failure of the jam releases a large water wave that results in high speeds and rapid stage rises at downstream locations (Beltaos and Krishnappen, 1982). Eyewitness accounts of rapid and dramatic increases in water level during spring break-up (Gerard, 1975, 1979) can only be explained by the action of surges (Mercer and Cooper, 1977; Henderson and Gerard, 1981; Beltaos and Krishnappen, 1982; Joliffe and Gerard, 1982). The ice jam longitudinal water surface profile has a significant effect on the resulting surge.

Investigations by Henderson and Gerard (1981) showed that the downstream surge cannot have a height greater than one-half of the difference in water level across the original jam. Beltaos and Krishnappen (1982) found that surge speeds are approximately proportional to the square root of the initial water surface slope at the jam toe. The longer the jam the greater the peak surge stages and duration of the surge velocities. In order to gain preliminary understanding of the ice jam surge problem, the longitudinal water level profile along and downstream of an ice jam must be known shortly before release. The profile is used to define the initial conditions and the extent of the surge upon release.

Study Area

The study area is a 23 km stretch of the Liard River, extending upstream from its junction with the Mackenzie River in the Northwest Territories (Figure 2). The Liard enters the Mackenzie at the 335 km point of its 1800 km route from Great Slave Lake to the Beaufort Sea. The village of Fort Simpson (61°53′N, 121°22′W) is situated at the confluence of the two rivers.

The Liard and Mackenzie rivers are ice covered 50% of the year. In most years, spring break-up of the Mackenzie is initiated by flow from the Liard. This occurs in late April to mid May, when spring temperatures in the Liard headwaters increase earlier than in the northern, downstream parts of the basin.

The morphological setting of the Liard river mouth is highly conducive to ice jamming. The river expands from a relatively consistent width of 700 m to almost 2800 m within approximately 10 km of the river mouth, 90% of which is either island or shoal area. The water slope decreases from 0.00039 to only 0.00005 from 20 km to the mouth

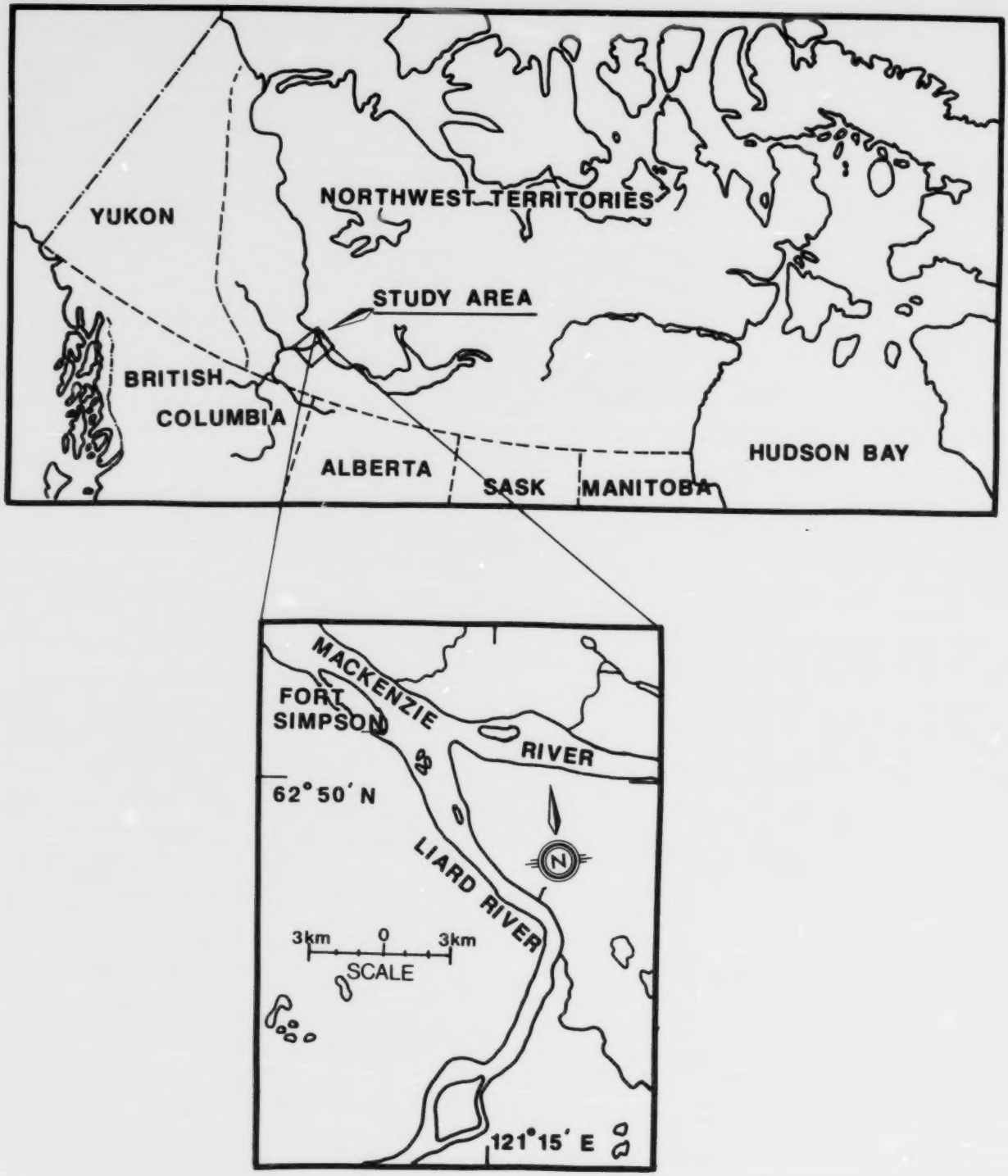


Figure 2. Study area — Liard/Mackenzie river confluence N.W.T.

TABLE 2
Flight line data of ice jam aerial photography.

ROLL #	DATE	LOCATION CODE	LINE	FRAMES	FLYING HEIGHT (m)	TIME (GMT) BEGIN	TIME (GMT) END	FOCAL LENGTH (mm)
A23690	May 11, 1974	LLO-17 $UM_{FS}335$	Z-1-N	244-254	2438.4 (8000 ft)	16:24	18:43	151.69
		LL17-27	Z-4N	224-235	2438.4 (8000 ft)	17:09	17:11	151.69
A24030	May 10, 1975	LLO-12 $UM_{FS}335$	M-7NW	14-26	2438.4 (8000 ft)	00:02	01:28	151.69
A24639	May 02, 1977	LLO-18 $UM_{FS}335$	M-7s (77-121)	186-202	2438.4 (8000 ft)	00:07	01:48	151.69
A24861	May 05, 1978	LLO-12 $UM_{FS}335$	78-35NW	26-49	2072.6 (6800 ft)	17:00	18:41	151.69
A25129	May 14, 1979	LLO-14 $UM_{FS}335$	79-35SE	29-43	2743.2 (9000 ft)	15:45	17:51	151.69
A25414	May 01, 1980	LLO-15 $UM_{FS}335$	80-11	39-54	2438.4 (8000 ft)	16:25	18:50	151.69
		LL12-25	80-10	27-38	2438.4 (8000 ft)	17:19	17:23	151.69

(Prowse, 1984, 1986a, b). Ice jams occur almost annually because of the extensive shoal area, drastic widening of the river, decreasing slope and water velocity.

The nature of ice on the Mackenzie also increases the chances of ice jamming at the Liard mouth. The Mackenzie ice still possesses much of its original mechanical strength by the time the Liard flood wave reaches the confluence. This is because of the stabilizing effects of Great Slave Lake (Prowse, 1984). Therefore it acts as a barrier to the downstream movement of Liard water and ice.

Since ice jams frequently occur at this location and are of some magnitude (e.g., 7.8 m thick and 22 km long, Prowse, 1984), their large-scale effects can be studied on a regular basis and provide insight into the processes of their formation, destruction and corresponding water levels.

Materials and Methods

Data Sources

The National Hydroloy Research Institute is involved with extensive documentation of ice break-up and jamming in the Liard/Mackenzie river confluence (Anderson, 1982; Prowse, 1984, 1986a, 1986b). Prior to 1980, insufficient data exist on ice jams at this site. Vertical aerial photographs of the ice jams have been obtained since 1974 during nine spring break-ups. Quantitative information about the jams from 1974 to 1980 is therefore restricted to that which can be extracted from the aerial photographs and official hydrometric data (Prowse, 1986b). These aerial photographs are the data base for the present study. Photography is not available for 1976.

Table 2 indicates the preliminary flight line information for the selected photography. The airphotos show the condition of the ice jams in the Liard River from its mouth at the Mackenzie as far as 25 km upstream.

Rectification of Aerial Photographs

Quantitative characteristics of terrain elements may be obtained from near-vertical aerial photographs by considering image distortions (Kudritskii *et al.*, 1966). Rectification of aerial photographs is the procedure by which image distortions such as photo scale variation and image displacement, resulting from relief change and tip-and-tilt of the airplane, are reduced. This procedure involves the use of "ground control". Ground control consists of a survey of measured horizontal control features and bench-marks which represent the actual distances or elevations of particular points appearing in the photos. When mutually identifiable on the ground and on a photo, ground control points are used to establish the exact spatial position and orientation of a photograph, relative to the ground, at the instant of exposure (Lillesand and Kiefer, 1979). Stereophotogrammetric measurements on the photos are then accurately extrapolated to represent the ground. The surveyed control points for this study were limited to sites along the Liard and Mackenzie river banks (Figure 3).

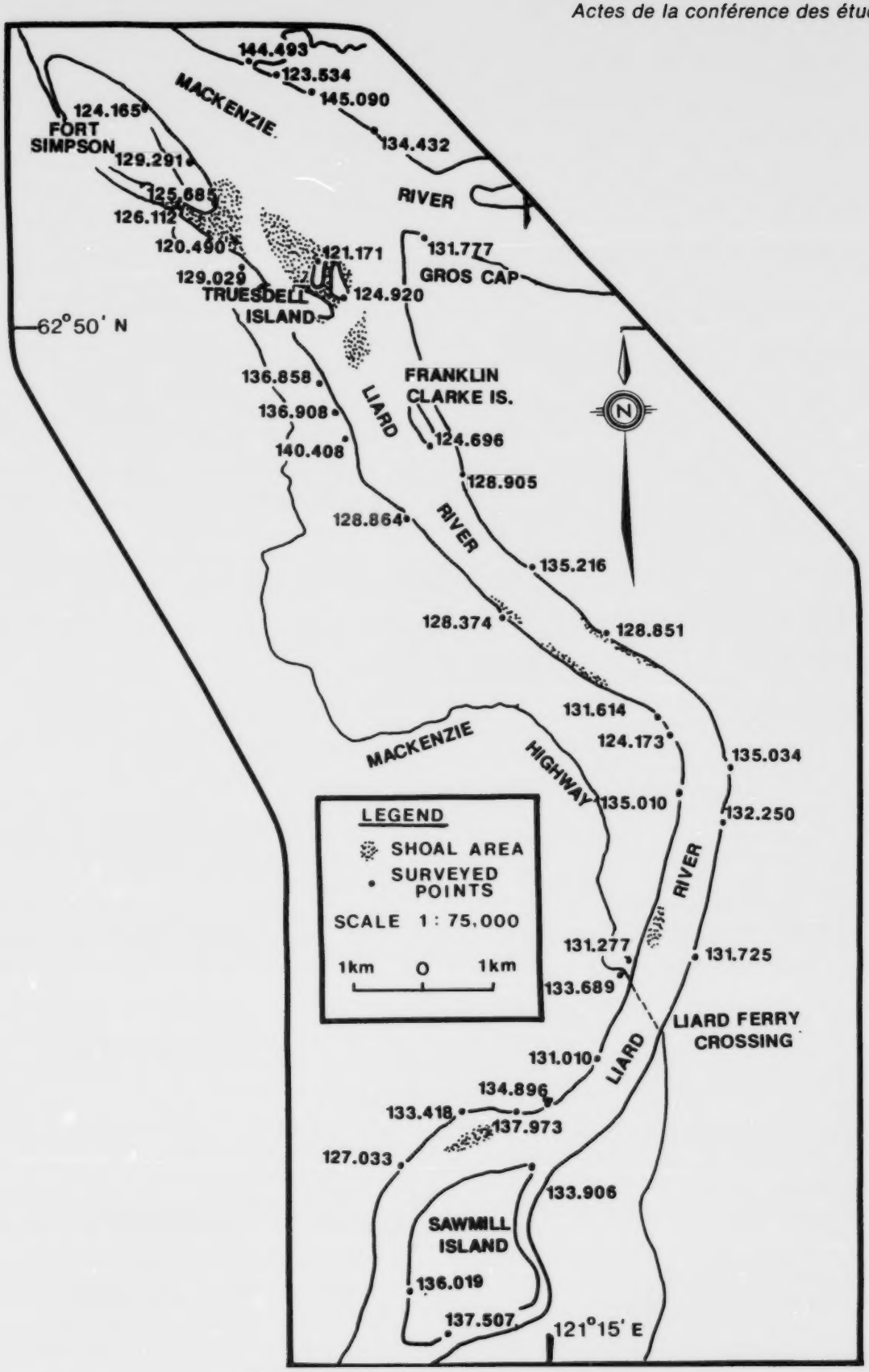


Figure 3. Location of surveyed vertical control points.

Instrumentation and Accuracy of Measurements

A Zeiss G-2 Stereocord, with accompanying microcomputer and plotter, was used to determine the surrogate field measurements of the ice jam water levels. The techniques used by Molchanov (1975) and Vlasov (1977) were too laborious and time-consuming for today's increasing need of real time ice information.

The G-2 Stereocord is an analytical stereophotogrammetric instrument which generates a three-dimensional model of the terrain based on control points from two photographs. The photo co-ordinates of the ground control points are measured stereoscopically, after which the computer calculates all the model orientation parameters. Positions measured in the stereo model are then transformed mathematically into ground co-ordinates and elevations. The analytical model provides a relatively true estimation of surface elevation points which are viewed, measured and interpreted.

The accuracy of the model initially depends on the accuracy of the ground control on which it is based. Control elevations were surveyed to within ± 0.001 m.

The accuracy of elevation differences is mainly affected by the error in measuring parallax difference. The maximum accuracy in measuring parallax change for the Zeiss G-2 Stereocord is 0.05 mm (± 0.01 mm). However, compounding the errors in surveying, model rectification and human error at all stages, measurement error can reach a maximum of ± 3.0 m (Aldred, 1984, personal communication). The sampling methodology used to determine the ice jam water level elevations produced an average maximum error of ± 0.32 m.

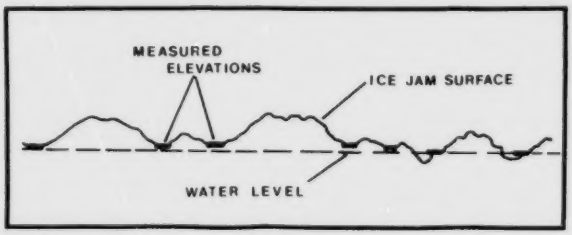


Figure 4. Location of water level measurements with respect to ice jam surface.

Sampling Procedures

A systematic, yet random pattern of data points was determined using an equidistant grid overlay. Each grid square was marked off with a bivariate graph and the axes labelled from 0–9. Pairs of random numbers were then used to locate the sample point in each grid square. This provided model-wide coverage and a randomly selected unbiased sample data set.

The grid of random data points was overlain on each stereomodel and over 40 elevation points were measured, with a concentration of points within the toe region. Several models contained less than the suggested number of elevations because of the absence of ice or decreasing width of the river. Each point was measured at the lowest elevation on the ice jam (Figure 4).

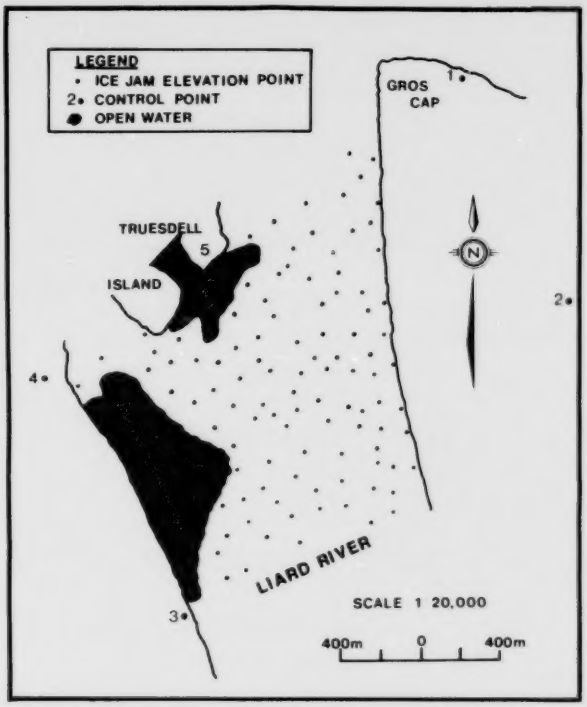


Figure 5. Typical model of ice jam surface showing measured elevation points (Model #4, May 1975)

Studies on the densities of floating freshwater ice indicate that approximately 8% of the ice mass lies above the water level (Adams, 1976, 1979; Ager, 1962). Therefore, the lowest points on the surface of the jam were assumed to represent the water level. Trapped water pools on the surface were considered to have a minor effect on the accuracy of the measurements. Each known elevation and water level point was measured five times (or more) and the average recorded on a 1:20 000 map of the model. The map's configuration corresponds to the calculated control parameters of the analytical model. It represents the base map for the ice and water level elevation analysis. One map (or model) covers 1–3 km of the ice jam section. Approximately 7 to 15 models were created for each ice jam. Figure 5 represents a typical model.

Initially, the elevations of both ice peaks and troughs were measured. It was decided that a contour map would provide the best visual interpretation of variability in surface elevations, and indicate those areas closest to the water level. The results proved to be inconclusive. A denser network of elevation points was required to accurately represent the microrelief of the ice jam surface. The peaks of isolated hummocks, shear zones and rubble piles were only sampled locally to determine their relative height.

According to the "Granular Mass Theory" of ice jams, in order to accurately represent the water level profile through an ice jam, the ice mass must be assumed to be floating. Flow hydraulics through grounded ice jams are not yet known.

Certain river sections were ascertained to be grounded through careful inspection of the configuration of the photographed ice jam surface, bathymetry maps and transects of local elevation differences. These extensively hummocked areas included river banks, heads of islands and shoal areas, particularly at the mouth of the Liard. The ice jam was considered to be floating in areas where its surface configuration appeared relatively uniform, usually over the deepest sections of the river.

It was impossible to statistically determine an accurate water level based on all of the measurements within one model because of the scattered floating and grounded conditions. Also, the variability across the model of the average relative error in estimates was quite large, ranging between $\pm 0.5 - \pm 1.0$ m.

Therefore, it was decided that a small square grid overlay be used to sample water levels within the most accurate area of the model. This method decreased the average relative error to a minimum and provided the most accurate water level estimates within the floating portions of the ice mass. A 2 cm^2 grid (approximately 400 m^2 of the ice jam surface) was overlain on the 1:20 000 model (at 0.5 km intervals), closest to the most accurate known elevation and in an area assumed to be floating. The sampling procedure adequately represented the small area of floating ice in the toe region (15%) and up to 75% of the floating ice area in the upstream sections. Ice accumulations along the river banks were not included.

The sampling method provides the most accurate data set. Table 3 lists the relative error and its respective direction for water level elevations in each model. The average maximum error was calculated to be ± 0.32 m for an average maximum error of 122.72 m above sea level (asl). This is well within the limits of error set out by other researchers ($\pm 0.3 - 0.5$ m) using the method of water level determination outlined by Gerard (1975).

On the other hand, elevation data were lost along the length of the jam as a result of the selection process for the most accurate data. In some years, only a small portion of the ice jam longitudinal water surface profile was interpretable. Also, the number of data points in the sample data set was reduced to a minimum of 3–31 values by using the 2 cm^2 grid to obtain representative water levels.

Analysis Procedures

The univariate statistics of the elevation data collected within the 2 cm^2 grid overlays are given in Table 4. Statistics were also calculated for the lowest 75%, 50% and 25% of the data in order to determine the best representative water level. Comparison of mean estimates in the vicinity of the known water levels revealed that the mean of all sampled points within the 2 cm^2 grid overlay provided the best surrogate water levels. Elevations through the jam were slightly higher than those which existed downstream of the toe and head. They approximated the theoretical, longitudinal water surface profile depicted in Figure 1 and the general flow hydraulics under an ice cover.

The mean elevations at their respective km intervals were graphed, along with the known instantaneous water levels

TABLE 3
Relative error of maximum water level elevations in each model

DATE	KM INTERVAL	KNOWN ELEVATION	MAX. ERROR OF KNOWN ELEVATION	MEAN MAX. ICE ELEVATION	MAX. ERROR ICE ELEVATION	N	AVERAGE MAXIMUM ERROR
May 11 1974	0.5	120.49	-0.22	120.28	-0.22	8	0.24
	6.0	124.70	+0.27	121.47	+0.26	8	
	11.0	131.61	+0.48	122.89	+0.45	3	
	12.5	135.03	-0.04	125.00	+0.04	4	
	15.5	133.69	-0.13	125.81	-0.12	8	
	16.0	133.69	+0.01	129.47	+0.01	3	
	18.5	134.90	-0.45	128.35	+0.43	3	
	20.0	133.42	+0.16	129.38	-0.35	3	
May 10 1975	4.0	134.34	+0.28	122.33	+0.28	18	0.25
	5.5	140.41	-0.20	120.79	-0.17	13	
	8.5	128.37	-0.16	120.34	-0.15	17	
	10.0	128.85	+0.55	120.75	+0.52	20	
May 02 1977	-0.5	129.29	-0.03	118.46	-0.03	7	0.33
	0.0	124.89	+0.46	120.56	+0.44	14	
	1.0	125.89	+0.46	121.76	+0.45	15	
	2.0	124.76	+0.08	120.22	+0.08	12	
	4.5	136.86	-0.69	121.25	-0.61	9	
	4.5	136.86	-0.89	121.38	-0.79	9	
May 05 1978	1.5	129.03	±0.39	127.83	±0.39	31	0.39
	2.5	125.10	±0.59	123.19	±0.58	19	
	3.0	124.92	-0.47	123.04	-0.46	25	
	4.5	136.91	±0.16	123.92	±0.14	20	
	5.5	140.41	±0.36	124.99	±0.32	20	
	7.0	128.86	-0.36	125.06	-0.35	20	
	8.5	128.37	-0.24	123.12	-0.23	23	
	9.5	128.66	±0.56	124.06	±0.54	18	
	10.5	128.85	+0.47	127.40	±0.46	24	
May 14 1979	0.0	129.29	+0.16	118.59	+0.15	12	0.21
	1.5	120.49	+0.20	120.14	+0.20	14	
	4.0	136.86	+0.36	124.67	+0.33	13	
	5.5	124.70	±0.27	123.62	±0.27	18	
	7.0	128.86	±0.13	123.62	±0.12	14	
	10.0	128.85	-0.31	122.42	-0.29	14	
	11.0	131.61	+0.13	125.54	+0.12	17	
May 01 1980	9.0	135.22	-0.68	118.54	-0.60	12	0.52
	10.5	131.61	+0.55	120.67	+0.50	14	
	15.5	131.74	+0.51	121.84	+0.47	14	
		Average Max. Elevation		122.72	Average Max. Error		±0.32

TABLE 4
Univariate statistics of water level elevation (asl) data collected within grid overlays.

DATE	KM INTERVAL	MAX.	MIN.	MEAN	ST.DEV.	VAR.	C.V.	N	STD. ERROR MEAN	95% CONFIDENCE LIMITS
May 11 1974	1.5	120.28	118.05	118.49	0.67	0.45	0.56	8	0.24	+0.45
	6.0	121.47	120.02	120.87	0.48	0.24	0.41	8	0.17	-0.33
	11.0	123.26	122.38	122.84	0.44	0.20	0.36	3	0.26	-0.74
	12.5	125.00	122.61	123.61	1.13	1.32	0.93	4	0.57	-1.93
	15.5	125.81	121.40	122.89	1.44	2.06	1.17	8	0.51	+0.46
	16.0	129.47	126.42	128.12	1.55	2.42	1.21	3	0.90	+2.62
	18.5	128.35	127.03	127.73	0.66	0.44	0.52	3	0.38	-1.11
	20.0	129.38	126.79	127.80	1.39	1.92	1.08	3	0.80	+2.34
May 10 1975	4.0	122.33	116.10	118.48	1.85	3.43	1.56	18	0.44	-0.76
	5.5	120.79	117.18	118.29	1.09	1.19	0.88	13	0.29	+0.92
	8.5	120.34	116.54	118.52	1.11	1.22	0.93	17	0.27	+0.47
	10.0	120.75	118.27	119.61	0.76	0.57	0.63	20	0.17	-0.29
May 02 1977	-0.5	118.46	116.15	117.041	0.79	0.63	0.68	7	0.30	+0.58
	0.0	120.56	117.27	118.93	1.01	1.02	0.85	14	0.27	+0.48
	1.0	121.74	117.31	119.36	1.43	2.11	1.22	15	0.38	+0.66
	2.0	120.22	117.35	118.64	0.80	0.64	0.67	12	0.23	-0.41
	3.5	121.25	117.85	119.73	1.40	1.96	1.17	9	0.47	+0.87
	4.5	121.38	117.41	119.421	1.26	1.59	1.06	9	0.42	+0.49
May 05 1978	1.5	127.83	121.60	124.05	1.84	3.37	1.52	31	0.34	+0.95
	2.5	123.19	118.20	119.93	1.44	2.06	1.20	19	0.33	+0.57
	3.0	123.04	118.44	120.80	1.07	1.15	0.89	25	0.21	+0.37
	4.5	123.92	121.87	122.78	0.61	0.37	0.49	20	0.14	+0.23
	5.5	124.99	120.89	122.99	1.10	1.20	0.89	20	0.25	+0.42
	7.0	125.06	121.13	122.63	1.23	1.51	1.00	20	0.27	+0.45
	8.5	123.12	120.99	122.16	0.51	0.26	0.42	23	0.11	+0.18
	9.5	124.06	123.18	123.72	0.20	0.04	0.17	18	0.05	+0.08
	10.5	127.40	123.00	125.54	1.34	1.80	1.07	24	0.27	+0.47
May 14 1979	0.0	118.59	116.14	117.22	0.71	0.50	0.61	12	0.21	-0.47
	1.5	120.14	118.37	119.04	0.45	0.20	0.37	14	0.12	-0.21
	4.0	124.67	122.86	123.66	0.61	0.37	0.50	13	0.17	-0.30
	5.5	125.59	122.37	123.73	0.87	0.76	0.71	18	0.21	+0.36
	7.0	123.62	121.82	122.68	0.47	0.22	0.38	14	0.13	+0.22
	10.0	122.42	121.59	122.09	0.22	0.05	0.18	14	0.54	+0.10
	11.5	125.54	123.04	124.22	0.71	0.51	0.57	17	0.17	+0.30
May 01 1980	9.0	118.54	116.44	117.35	0.63	0.40	0.54	12	0.12	+0.33
	10.5	120.67	116.52	118.18	1.17	1.38	0.99	14	0.31	-0.56
	15.5	121.84	120.42	121.17	0.42	0.10	0.27	14	0.09	-0.15

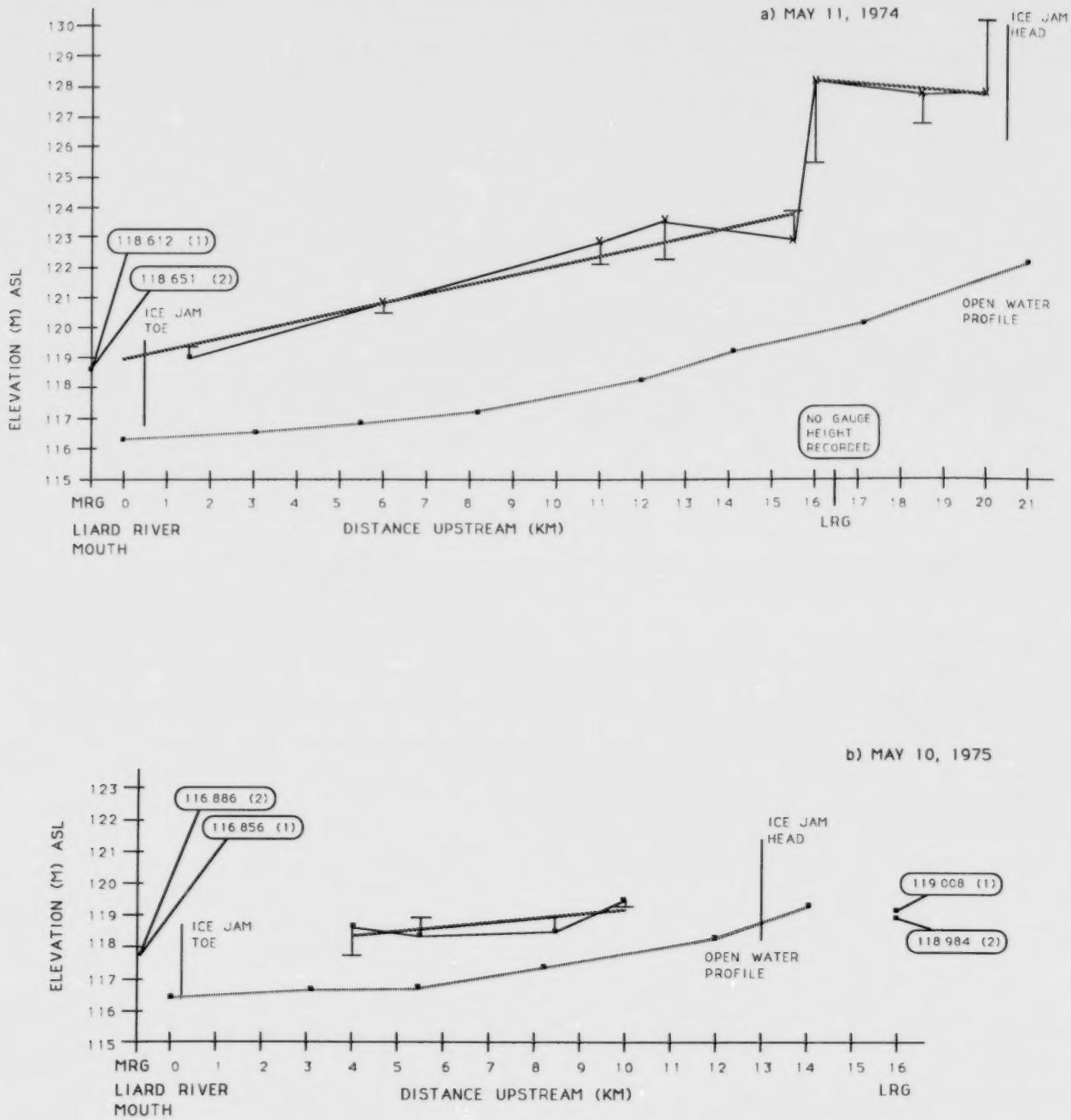
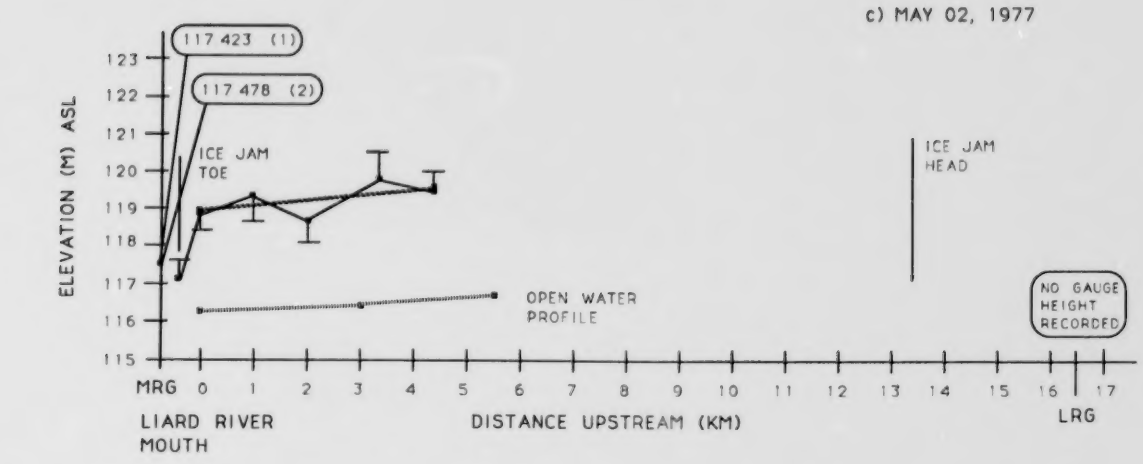


Figure 6a-f. Longitudinal water surface profiles of ice jams Liard/Mackenzie river confluence (1974–1980)



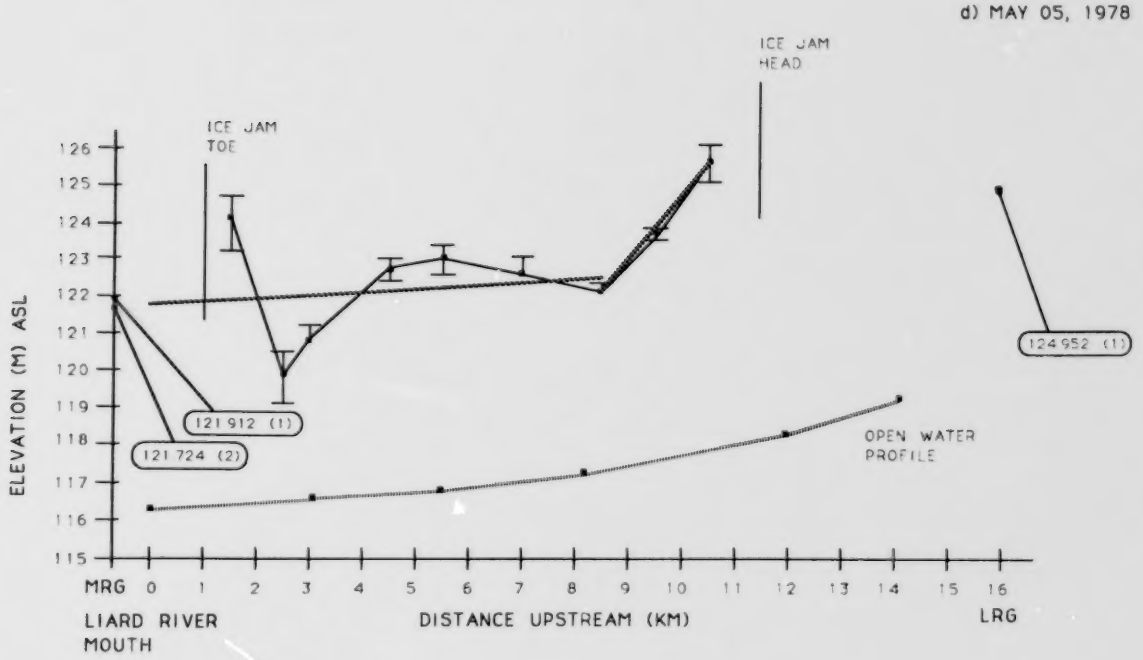
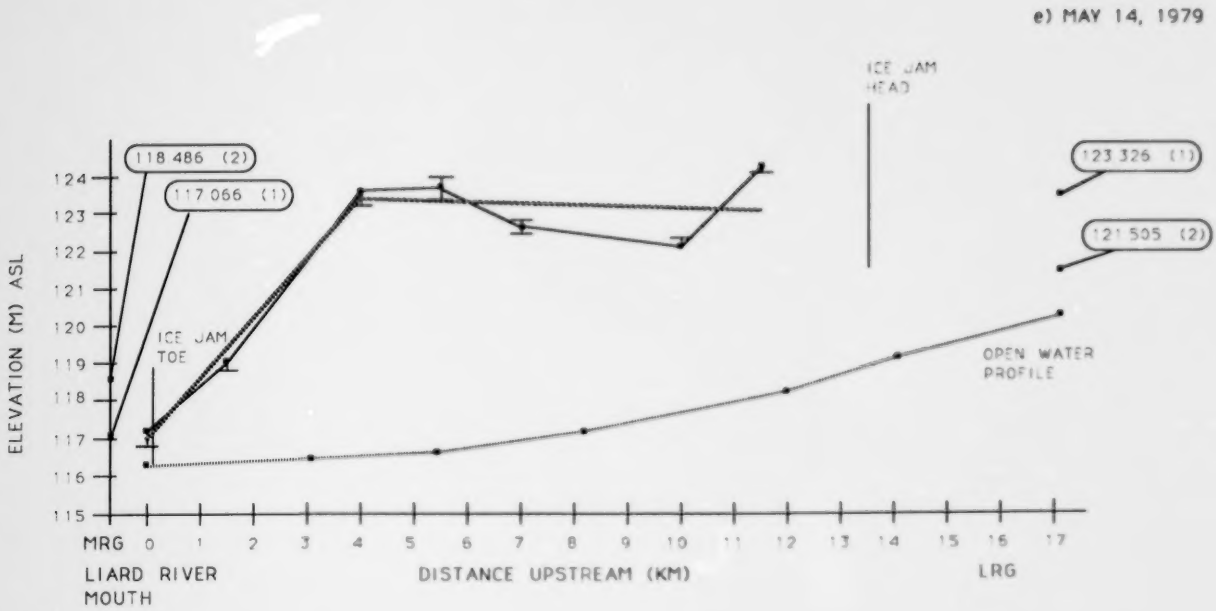


Figure 6a-f. Continued



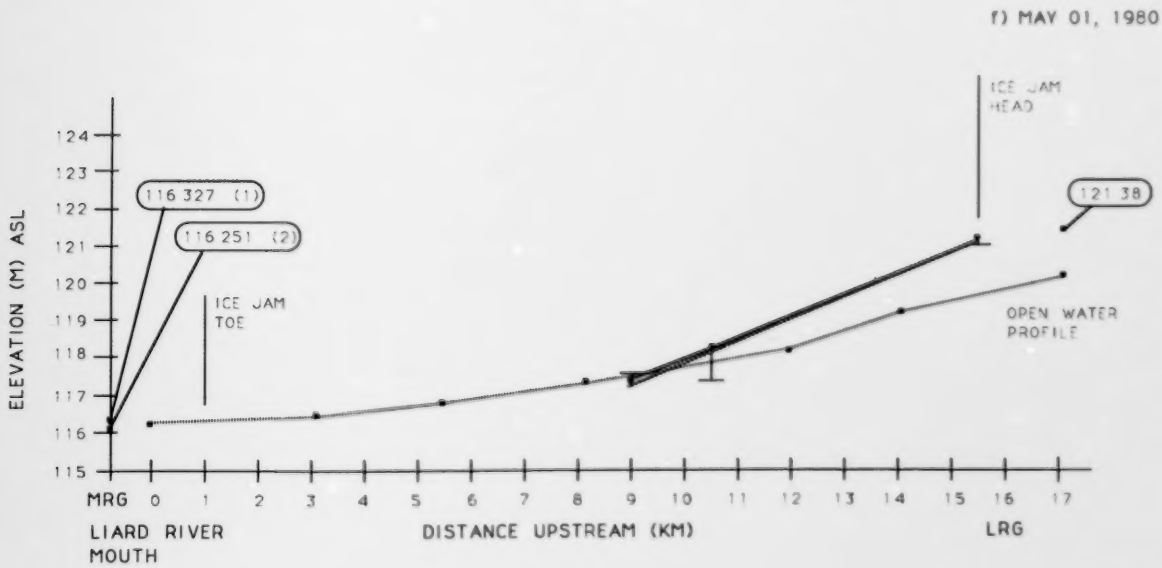


Figure 6a-f. Continued

TABLE 5
Instantaneous water levels corresponding to aerial photograph flight

	DATE	TIME (GMT)	GAUGE	BASE DATUM	WATER ELEVATION
Mackenzie River Gauge # 10GC001	May 11, 1974	16:24	7.907	110.705	118.612
		18:43	7.946	"	118.651
	May 10, 1975	00:02	6.151	"	116.856
		01:28	6.181	"	116.886
	May 02, 1977	00:07	6.718	"	117.423
		01:48	6.773	"	117.478
	May 05, 1978	17:00	11.207	"	121.912
		18:41	11.019	"	121.724
	May 14, 1979	15:45	6.361	"	117.066
		17:51	7.781	"	118.486
	May 01, 1980	16:25	5.622	"	116.327
		18:50	5.546	"	116.251
Liard River Gauge # 10ED002	May 11, 1974	No gauge height record			
	May 10, 1975	00:02	3.109	115.899	119.008
		01:28	3.085	"	118.984
	May 02, 1977	No gauge height record			
	May 05, 1978	16:15	9.053	115.899	124.952
		No chart record			
	May 14, 1979	15:45	7.427	115.899	123.326
		17:51	5.606	"	121.505
	May 01, 1980	No gauge height record			

calculated from the Mackenzie (#10GC001) and Liard (#10ED002) water gauge chart records (Figure 6a-f). Known water levels corresponded to the times at which the aerial photograph session began and ended (Table 5). The open water profile was measured in the field by British Columbia Hydro in 1980 (Table 6).

TABLE 6
Open water slopes measured in the field by British Columbia Hydro, October 11-13, 1980.

DISTANCE FROM LIARD MOUTH (km)	WATER LEVEL ELEVATION (m asl)	CHANGE IN WATER (m)	DISTANCE CHANGE (km)	SLOPE (m/m)
0.0	116.29	1.28	3.1	0.00005 - (Prowse,
3.1	116.45	0.32	2.4	0.000133 1986a)
5.5	116.77	0.50	2.8	0.000178
8.3	117.27	0.95	3.7	0.000258
12.0	118.22	1.04	2.1	0.000482
14.1	119.26	0.89	3.1	0.000292
17.2	120.15	1.86	3.7	0.000491
21.0	122.01	0.40	1.6	0.000258
22.6	122.41	0.35	.9	0.000354
23.5	122.76			

A "best fit line" was also drawn between evident groups of mean elevations. Linear regression uses a straight line as the "best fit curve" for the data. The line is represented by the equation $Y = mX + b$, where "m" equals the slope of the line and "b" equals the Y-intercept. The regression parameters of the elevation data for each year are given in Table 7.

TABLE 7
Regression parameters of "best fit line" through estimated water levels.

DATE	DISTANCE FROM MOUTH (km)	SLOPE (m/m)	INTERCEPT (m)	R^2	REGRESSION EQUATION
May 11,1974	0.0-15.5	0.000318	118.88	0.86	y = 0.3187(X) + 118.88
	16.0-20.0	-0.000088	129.48	0.72	y = -0.0877(X) + 129.48
May 10,1975	4.0-10.0	0.000165	117.57	0.57	y = 0.1648(X) + 117.57
May 02,1977	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May 05,1978	1.5- 8.5	0.000073	121.85	0.02	y = 0.0730(X) + 121.85
	8.5-10.5	0.000172	107.53	0.98	y = 1.7150(X) + 107.53
May 14,1979	0.0- 4.0	0.001634	116.97	0.99	y = 1.6340(X) + 116.97
	4.0-11.5	-0.000030	123.50	0.01	y = -0.0301(X) + 123.50
May 01,1980	9.0-15.5	0.000590	112.02	0.99	y = 0.5900(X) + 112.02

Results

The configuration of the ice jam longitudinal water surface profiles and "best fit lines" for each year are interpreted with respect to the river regime and jam morphology. Their shapes denote the effects of grounded ice accumulations and the extent of backwater. Water surface slopes through various sections of the jam are then compared to the average open water slopes that exist over the same sections (Figure 7a-f). This was done to determine if "equilibrium ice jam theory" is applicable to the jam formations.

May 11, 1974 (Figure 6a)

The longitudinal water surface profile is a unique example of an ice jam not yet formed. All but a 3 km section at the toe of the jam was moving. The moving ice created a false parallax under stereoscopic viewing which interfered with the accurate measurement of water levels through the floating sections of the jam. Therefore, the water level was represented by measurements taken at the base of stranded ice along the banks.

The first surrogate water level (at 1.5 km) corresponds well with the known elevation at the Mackenzie river gauge. The water level steepens progressively to 12.5 km, the slope of which (0.00044) is 3.6 times as great as the average open water slope of the same area (0.00012) (Figure 7a). The steeper water section of the toe region, characteristic of a typical stationary ice jam, had not yet formed. The jam was just beginning to form.

There are negative anomalies in the profile between 12.5 km and the ice jam head at 20 km. A negative water surface slope indicates that the water is flowing backwards. There is no *recorded* proof of this phenomenon occurring in reality. However, during break-up of the Athabasca River, near Fort McMurray, Alberta, Rickert (1986, Alberta Environment, personal communication) observed a rebound wave, the width of the river, moving upstream after striking an obstacle or wall of ice in the river. This evidence may warrant its further research. The decline of the water level actually corresponds to a constricted section of the river. The aerial photography showed extensively rubbled ice accumulations built up along the banks (due to large shoal areas within this section), restricting the river channel to a small flow section within the centre of the river. Negative slopes are a result

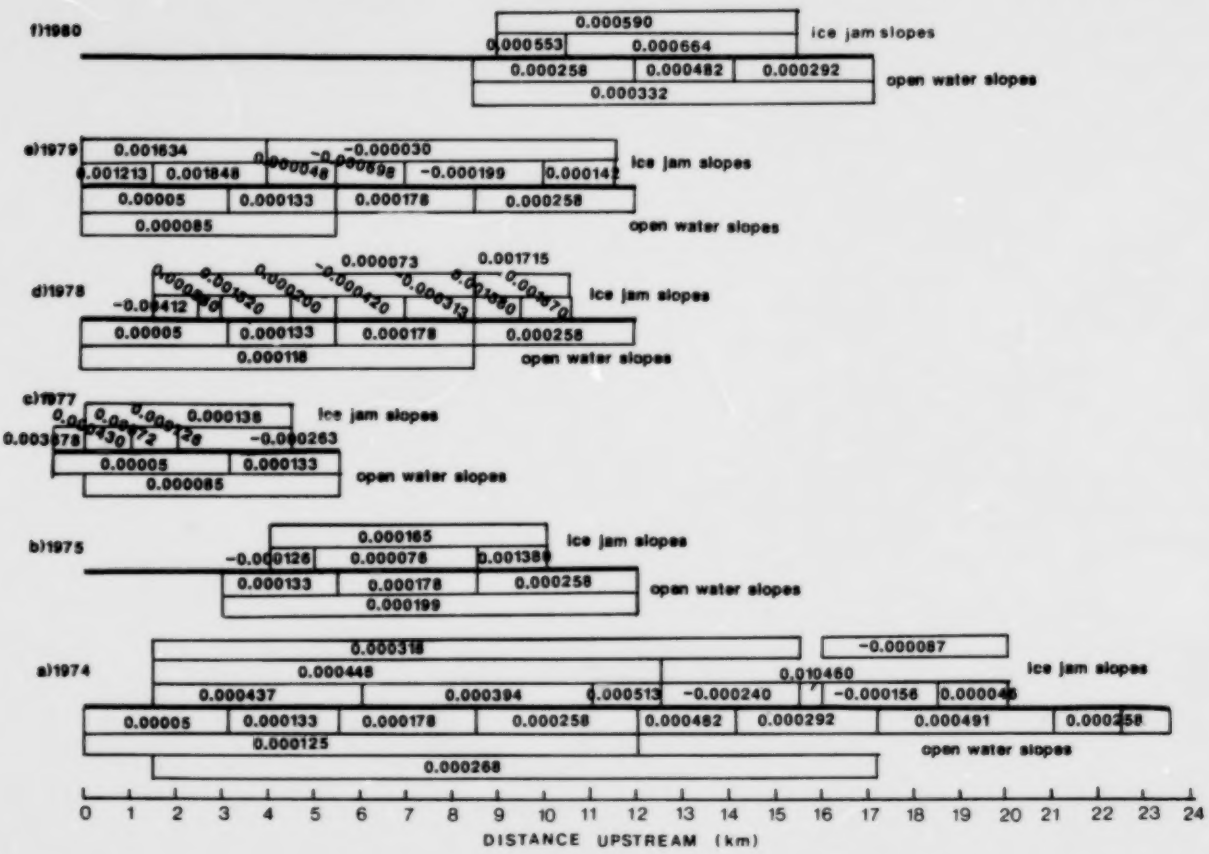


Figure 7a–f. Comparison of ice jam and open water slopes

of the large variability of measured elevations within grounded ice. Mean water levels may over-estimate actual water levels. However, there was no available known water level at the Liard river gauge for comparison. Presumably, the stage recording orifice was destroyed by the accumulating ice.

The profile upstream of the obstruction depicts a steep water level rise. The backwater section was approximately 7–8 m above the open water level. Backwater from the ice jam toe at the Liard river mouth was between 2–5 m.

May 10, 1975 (Figure 6b)

The surrogate field elevations represent water level estimates within a stationary jam. Only those estimates in the central section of the ice mass were interpretable. This was a result of lost data at the toe and head regions due to their high relative error (>0.5 m). The profile indicates a negative slope between 4.0 and 5.0 km. This is most likely due to the effects of grounding in the toe region, owing to the low water levels. The ice cakes within the 5.0 to 8.5 km section appeared to be more compacted than any other part of the jam. The constricted channel corresponds with the low-level profile through the jam, followed by a sharp rise in water level at 8.5 km (slope = 0.001380). The slopes of these sections do not equal open water slopes. However, the "best fit line" between 5.0 and 8.5 km is close (Figure 7b).

The longitudinal profile indicates low water levels with no appreciable backwater section (1 m). The hydraulic resistance of the ice is low, therefore compression forces are weak. Release of this jam would not produce a surge of great magnitude to downstream locations.

May 02, 1977 (Figure 6c)

The most accurate interpretable section of this jam is in the toe region from the Mackenzie river gauge to 4.5 km upstream the Liard. The slope of the steep section at the toe (0.003678) is 70 times as great as the open-water profile (0.00005). Low water levels, exposed shoal areas and extensively rubbled ice indicate that the toe region is grounded, with an extremely restricted flow channel, to about 5.0 km upstream. The average water surface slope (best fit line) through the rubbled area (0.000138) is approximately 1.6 times as great as the open-water profile over the same area (0.000085) (Figure 7c). The "best fit line" represents the level of water infiltrating through the restricted section. A moderate water level rise (2–3 m) was created by the jam.

May 05, 1978 (Figure 6d)

The longitudinal profile shows extreme local variability of ice jam water levels in the toe region. The ice jam surface on the aerial photography appeared rubbled and compacted, more so than any other year. One would assume the ice was free to move downstream because of high water levels and open water in the Mackenzie. This was not the case. A large section of the jam was grounded at the mouth of the Liard river. Isolated ice accumulations over a large portion of the jam (0.0–7.0 km) were measured to be 1–4 m high. This variability created the uninterpretable anomalies in the profile.

The "best fit line" through the estimates closely corresponds with the elevation recorded at the Mackenzie river gauge. It represents the level of water infiltrating through the grounded section. Water levels are 5–6 m in excess of the open-water base flow. The slope of the line (0.000072) is 1.6 times less than the average open-water slope (0.000118) (Figure 7d).

A large steep backwater section begins at 8.5 km. Its slope (0.001715) is 7 times that of the open-water slope, creating a 6–7 m backwater section.

May 14, 1979 (Figure 6e)

This ice jam produced the largest initial increase in water level at the Liard river mouth of all the study years. The surrogate Mackenzie water elevation (117.22) well represents that which was obtained from the Mackenzie river gauge record (117.006). From this point, the water level increases at a rate of 1.6 m km^{-1}, reaching a maximum rise of 7–8 m at 4.0 km upstream.

The slope of this area (0.001634) is 20 times as steep as the open water slope (0.000085) (Figure 7e). Such a large backwater section indicates that the hydraulic flow resistance of the jam is also large. A constricted or grounded toe region creates the high backwater levels. However, through the backwater section, the measured profile and best fit line denote a negative slope. The elevation points within the grounded zone between 4.0–5.0 km are creating the anomalies.

The negative slopes may also be caused by the change in water level during the aerial photograph flight. The water levels at the Mackenzie and Liard river gauges were recorded to be 117.066 and 123.320 m (asl) at the beginning of the flight. Sometime during the upstream photo session, the water levels receded 2.0 m (at Liard river gauge) and rose 1.5 m at the Mackenzie gauge. The upstream water level measurements may have recorded the receding water levels.

May 01, 1980 (Figure 6f)

Only the last 6 km (9.0–15.5) of mean ice jam water levels were interpretable. Low known water levels and the presence of large open-water areas in the jam section indicate there is very little resistance to flow. The slope of the longitudinal profile and best fit line (0.00059) is slightly steeper than the average open-water slope (0.000332). A low backwater section of approximately 1 m was created.

The missing downstream section of the profile is assumed to be close to the open-water profile. A relatively smooth ice cover and no slush present under the ice create equal slopes between closed and open-channel periods (Nezhikhovskij, 1964).

Discussion

Stereoscopic aerial photographs of ice jams in the Liard/Mackenzie river confluence are applicable as a source for surrogate water level and ice jam field measurements. The most accurate method for determining water levels through the jam, using a Zeiss G-2 Stereocord, is:

1. Rectify aerial photographs as accurately as possible.
2. Select an area within the stereo model where the ice jam is assumed to be floating.
3. On the stereo model, overlay a square grid onto a floating section of the jam closest to the most accurate known elevation of the model. Calculate the error in measurements with respect to this elevation.
4. Make over 40 elevation measurements, within the grid, of the lowest points on the surface of the jam.
5. The mean of all water levels in the selected grid area produces the most accurate surrogate field measurement of the water level.

An increase in the accuracy of rectification procedures and the number of measured elevation points in each grid section may have produced more conclusive results for this study. The addition of accurate known elevations (less than ± 0.5 m) eliminates the possibility of missing data. A larger sample of water level elevations produces a more representative mean value of the actual water level.

The paper explains the configuration of the stereoscopically-determined ice jam water surface elevations with respect to the meso and microscale variability of the ice jam surface. This depends to some degree on the presence of shoal areas, volume of ice and accumulation patterns. The surrogate field measurements of the longitudinal water surface profiles adequately represented:

1. approximate water levels and slopes through grounded and floating sections of the ice jams,
2. effects of extensively rubbled ice on water level estimates,
3. backwater extent,
4. initial conditions for ice jam surge characteristics.

Anomalies such as negative water surface slopes are a result of the large variability of measured elevations on the surface of grounded ice, as well as transient surges of the ice and water flow. Extensively hummocked ice can create elevation changes of one metre or more within localized areas. The average of these elevation differences can create higher than normal water level estimates. A comparison of Table 4 and Figures 6a-f indicates that negative slopes correspond to river sections with the highest coefficients of variation (measure of variability). These sections are shoal or constricted areas where grounding can occur.

Ice jams with distinct toe sections are formed as a result of extensive ridging and compression forces within the toe region. This dynamic mechanism of formation produces the steepest water surface slopes (Chizov, 1975). None of the ice jam water slopes was equal to the open-water slopes, therefore no equilibrium sections were formed.

Surrogate field measurements of the ice jam and corresponding water levels are obtained safely and economically. They provide a six-year historical data base of ice jam and water level measurements of the Liard/ Mackenzie river confluence, N.W.T. The proposed technique may be applicable to other inaccessible areas prone to ice jam occurrences.

Acknowledgments

I wish to acknowledge the generous support of the following individuals and organizations: Dr. Terry Prowse of the National Hydrology Research Institute for his professional support and extensive knowledge of ice jam phenomena; Dr. Peter Adams of Trent University for his reviews, helpful advice and financial support; the National Hydrology Research Institute for financial support and provision of the aerial photography; the Northern Scientific Training Program for financial assistance; and Dendron Resources Survey Ltd. for loan of the Zeiss G-2 Stereocord and accompanying software. Many other people have provided assistance during this project and I take this opportunity to acknowledge their contributions and express my gratitude.

References

Adams, W.P. 1976. Field determination of the densities of lake ice sheets. Limnology and Oceanography. 21:602–8.

_____, Barr, D.R., Glew, J.R. Hurford and Stillman, M.W. 1979. Lake ice density in the environment — practical approaches to measurement and calculation. Ecology Bulletin, Trent University, Biology Department, Peterborough, Ontario, 4(1):1–24.

Ager, B.H. 1962. Studies on the density of natural and artificially formed freshwater ice. Journal of Glaciology, 4:207–14.

Aldred, A.H. 1984. Dendron Resources Survey Ltd., Ottawa Ontario. Personal communication.

Andres, D.D. and Rickert, H.A. 1984. Observations of the 1983 breakup in the Athabasca River Basin upstream of Fort McMurray, Alberta. Internal Report No. SWE 84-1, Civil Engineering Dept., Alberta Research Council. 36 p.

_____ and Doyle, P.F. 1984. Analysis of breakup and ice jams on the Athabasca River at Fort McMurray, Alberta. Canadian Journal of Civil Engineering, 11:444–58.

Anderson, J.C. 1982. Liard and Mackenzie River ice breakup, Fort Simpson Region, N.W.T., 1982. National Hydrology Research Institute, Environment Canada report for Water Resources Division, Indian and Northern Affairs Canada, Ottawa, Ontario. 37 p.

Beltaos, S. and Wong, J. 1984. Downstream transition of river ice jams. National Water Research Institute. Inland Waters Directorate, Environment Canada. 43 p.

_____. 1981. Ice freeze-up and breakup in the Lower Thames River: 1979–80 observations. Environmental Hydraulics Section, Hydraulics Division, National Water Research Institute, Canada Centre for Inland Waters. 30 p.

_____. 1983. River ice jams: theory, case studies and applications. Journal of Hydraulic Engineering, ASCE, 109(10):1338–59.

_____ a. 1984. Study of river ice break-up using hydrometric station records. Proceedings of Workshop on the Hydraulics of River Ice, NRCC Subcommittee on Hydraulics of Ice-Covered Rivers, June 20–21, New Brunswick. 41–59.

_____ b. 1984. A conceptual model of river ice breakup. Canadian Journal of Civil Engineering, 11(3):516–29.

_____ and Krishnappen, B.G. 1982. Surges from ice jams: A case study. Canadian Journal of Civil Engineering, 9(2):276–84.

Berdennikov, V.P. 1965. Physical characteristics of ice in ice jams and ice gorges. Soviet Hydrology: Selected Papers, 4:384–402.

Calkins, D.J. 1983. Ice jams in shallow rivers with floodplain flow. Canadian Journal of Civil Engineering, 10:538–48.

Chizov, A.N., ed. 1974a. Investigation and calculations of ice jams. Report 473. Draft translation. Cold Regions Research Engineering Laboratory, Hanover, New Hampshire.

_____. 1974b. The mechanism of ice jam formation; a classification of ice jams, translated from Trudy GGI, Trudy, Moscow: State Hydrological Institute, (227):3–17.

Doyle, P.F. and Andres, D.D. 1978. 1978 Breakup in the vicinity of Fort McMurray and investigation of two Athabasca River ice jams. Transportation and Surface Water Engineering Division, Alberta Research Council, Internal Report No. SWE-78/05. 40 p.

_____ and Andres, D.D. 1979. Spring breakup and ice jamming on the Athabasca River near Fort McMurray. Transportation and Surface Water Engineering Division, Alberta Research Council, Internal Report No. SWE-79/05. 32 p.

Gerard, R. 1975. Preliminary observations of spring ice jams in Alberta. Proceedings of the Third Annual International Symposium on ice problems, International Association of Hydraulic Research, Hanover, New Hampshire, August 1975. 261–73.

_____. 1979. River ice in hydrotechnical engineering: a review of selected topics. Proceedings of the Canadian Hydrology Symposium, Cold Climate Hydrology, Vancouver, British Columbia, May 10–11. 1–29.

_____. 1984. Ice jam research needs. Workshop on the Hydraulics of River Ice, American Society of Civil Engineers, June 1984, Fredericton, New Brunswick. 181–93.

Henderson, F.M. and Gerard, R. 1981. Flood waves caused by ice jam formation and failure. International Symposium on Ice, International Association of Hydraulic Research, Quebec, July 1981. 277–97.

Joliffe, I. and Gerard, R. 1982. Surges released by ice jams. Proceedings of the Workshop on Hydraulics of ice covered rivers, Edmonton. 253–59.

Kudritskii, D.M., Popov, I.V. and Romanova, E.A. 1956. Hydrographic interpretation of aerial photographs. Report TT64–11094, published for U.S. Department of Commerce and National Science Foundation by the Israel Program for Scientific Translations. 40 p.

Lillesand, T.M. and Kiefer, R.W. 1979. Remote Sensing and Image Interpretation, Toronto, Ontario: John Wiley and Sons Inc. 612 p.

Mackay, D.K., Sherstone, D.A. and Arnold, K.C. 1974. Channel ice effects and surface water velocities from aerial photography of Mackenzie River break-up. Environmental-Social Committee, Northern Pipelines, Canadian Task Force on Northern Oil Development, Report 74–12. 73–107.

Mercer, A.G. and Cooper, R.H. 1977. River bed scour related to the growth of a major ice jam. Proceedings, 3rd National Hydrotechnical Conference, Quebec City. 291–308.

Michel, B. 1971. Winter regime of rivers and lakes, Monograph 3, Cold Regions Research Engineering Laboratory, Hanover, New Hampshire. 131 p.

_____. 1983. Comparison of field data with theories on ice cover progession in large rivers. Paper submitted for publication to the Canadian Journal of Civil Engineering, June 8, 1983.

Molchanov, A.K. 1975. The use of stereophotogrammetry in measuring fluctuations in water stage during ice jams, translated from Trudy GGI, Gidrometeoizdat, No. 205, State Hydrological Institute, Leningrad, U.S.S.R. 62–5.

Molchanov, A.K. and Vlasov, V.P. 1974. Studying ice jams from aerial photographs, translated from Trudy GGI, No. 219, Hydrometeorological Press, State Hydrological Institute, Leningrad, U.S.S.R. 81–3.

Pariset, E., Hausser, R. and Gagnon, A. 1966. Formation of ice covers and ice jams in rivers. Journal of the Hydrological Division, American Society of Civil Engineering, 92(HY6):1–24.

Prowse, T.D. 1984. Liard and Mackenzie River ice break-up, Fort Simpson Region, N.W.T., 1983. National Hydrology Research Institute, Environment Canada report for Water Resources Division, Indian and Northern Affairs Canada, Ottawa, Ontario. 73 p.

_____. 1986a. 1985 Breakup and ice jam observations, Liard and Mackenzie Rivers near Fort Simpson, N.W.T. National Hydrology Research Institute, Environment Canada report for Water Resources Division, Indian and Northern Affairs Canada, Ottawa, Ontario. 38 p.

_____. 1986b. Ice jam characteristics, Liard-Mackenzie River confluence, N.W.T. (submitted to Canadian Journal of Civil Engineering).

Rickert, H. 1986. River Engineering Branch, Alberta Environment, Edmonton, Alberta, personal communication.

Sherstone, D.A. 1973. Remote sensing techniques applied to current velocity measurements and river ice jamming. Proceedings of the Ninth Canadian Hydrology Symposium, Fluvial Processes and Sedimentation, University of Alberta, Edmonton, Alberta, May 8–9. 403–19.

Shulyakovskii, L.G. 1966. Manual of forecasting ice formation for rivers and inland lakes, translated from Russian, Israel Program for Scientific Translations, Jerusalem.

Uzunner, M.S. and Kennedy, J.F. 1976. Theoretical model of river ice jams. Journal of Hydrological Division, American Society of Civil Engineering, 102(HY9):1365–83.

Vlasov, V.P. 1977. Possible use of aerial photo surveys for the study of ice jams. Soviet Hydrology: Selected Papers, 16(1):15–16.

Wuebben, J.L. and Stewart, D.M. 1978. Physical measurement of ice jams. Special Report No. 78–3. Cold Regions Research Engineering Laboratory, Hanover, New Hampshire. 19 p.

HOLOCENE LAND EMERGENCE, WESTERN SIMPSON PENINSULA, N.W.T.

Andrew Webster

Department of Geography, Trent University, Peterborough, Ontario K9J 7B8

Level: Bachelor's

Abstract

Immediately following deglaciation at about 9500 BP, the Simpson Peninsula experienced a marine transgression to the extent that the only dry land consisted of peaks found mostly to the southwest, near the present settlement. Because regional rebound was extraordinarily rapid, approximately 75% of total land emergence had occurred by 7000 BP, by which time sea level stood around the present 50 m contour. The +200 m of emergence during that period left extensive raised beach complexes and other sedimentary evidence of former water planes, which were investigated by field, map, and photographic reconnaissance during August-September 1986.

This work has permitted the postglacial marine margin chronology to be established and mapped, showing the transformation of the study area from an archipelago to its present condition of towering relief and rapidly retreating embayments. Intact shells were discovered in glaciomarine silt at 258 m asl, higher than the 240–250 m asl marine limit previously identified. This suggests that land emergence is slightly greater than first thought.

Key words: Holocene, Arctic, Simpson Peninsula, marine limit, land emergence.

Résumé

Immédiatement après la déglaciation, vers −9500, la péninsule de Simpson subit une transgression marine, et les seuls points en émersion étaient les hauteurs situées surtout au sud-ouest, près de la localité actuelle. Comme le soulèvement s'est produit de façon extraordinairement rapide, environ 75% du sol de la région était exondé vers −7000, alors que le niveau de la mer atteignait la ligne hypsométrique actuelle des 50 m. La remontée du sol de plus de 200 m au cours de cette période a laissé de nombreuses plages suspendues et autres traces sédimentaires d'anciens niveaux de la mer, que l'auteur a étudiés sur cartes, sur photographies et sur place au cours d'août et de septembre 1986.

Cette exploration lui a permis d'établir la chronologie de l'émersion post-glaciaire du littoral de la région et de la cartographier, montrant ainsi la transformation d'un archipel en la péninsule actuelle au relief accentué, où les baies reculent rapidement. L'auteur a découvert des coquilles intactes dans des sédiments détritiques glacio-marins à 258 m d'altitude, plus haut que la limite de la transgression marine précédemment fixée à 240–250 m. Ce fait indique que la hauteur d'émersion est un peu plus grande qu'on ne le croyait.

Mots-clés: Holocène, Arctique, péninsule de Simpson, limite de la transgression marine, émersion des terres.

Introduction

During the catastrophic collapse of the Laurentide ice sheet, virtually all coastal areas in Arctic Canada experienced some degree of marine inundation, as late-glacial seas transgressed over the glacioisostatically depressed land surface. Recent reconstructions of the ice sheet at its Wisconsin maximum (e.g. Bryson *et al.*, 1969; Ives *et al.*, 1975; and Mayewski *et al.*, 1981), suggest that the ice sheet covered the entire northern mainland coast and nearly all of the Arctic Archipelago. Any land in the Canadian Arctic that may have escaped glaciation during the last advance would probably have been within the 100–300 km zone of depression which occurs between the margin of a continental ice sheet and the crustal forebulge (Walcott, 1972; Peltier, 1982). It appears, then, that all present-day coastal areas in Arctic Canada have undergone some isostatic recovery whether they were glaciated or not; similarly, they have all experienced marine transgression.

The maximum depth of marine inundation is estimated from the altitude of the marine limit, the highest evidence of a former shoreline. The evidence may be geomorphic, or in the form of preserved organic material known to have been formed or deposited in a nearshore environment. Due to differential crustal recovery, a marine limit is very point-specific. Observed marine limits may vary in elevation by tens of metres over distances less than 100 km. This reflects not only regional differences in ice thickness and duration of load, but also differences in dates of deglaciation and the pattern of ice retreat. Thus, the marine limit, depicted on maps of regional marine overlap, is diachronous. A marine limit, over distances of up to a few tens of kilometres, may be considered synchronous. This assumption is realistic considering that the observable evidence of a particular limit is generally fragmentary and restricted in spatial extent.

The elevation of the marine limit is a function of post-glacial isostatic uplift and eustatic (global average) sea level change. It takes no account of restrained rebound that occurred prior to deglaciation; that is, during decreasing ice loading associated with thinning of the ice sheet (Andrews, 1975). As the ice sheets ablated, water which had been abstracted from the oceans was returned as meltwater, causing a rise in sea level. Estimates of minimum sea level during the Wisconsin range from 80–200 m below present, but 120–130 m is the median range and the one considered realistic by most workers. Eustatic sea level curves for the Holocene are in fairly close agreement, showing an increase of about 30 m since 10 000 BP (eg. Shepard, 1963; Morner, 1969; Moran and Bryson, 1969). Consequently, the marine limit may underestimate the amount of postglacial rebound by 30 m. Modelling by Clark *et al.* (1978) shows that the eustatic component in the Arctic may have been negligible, so the 30 m rise may be taken as a maximum.

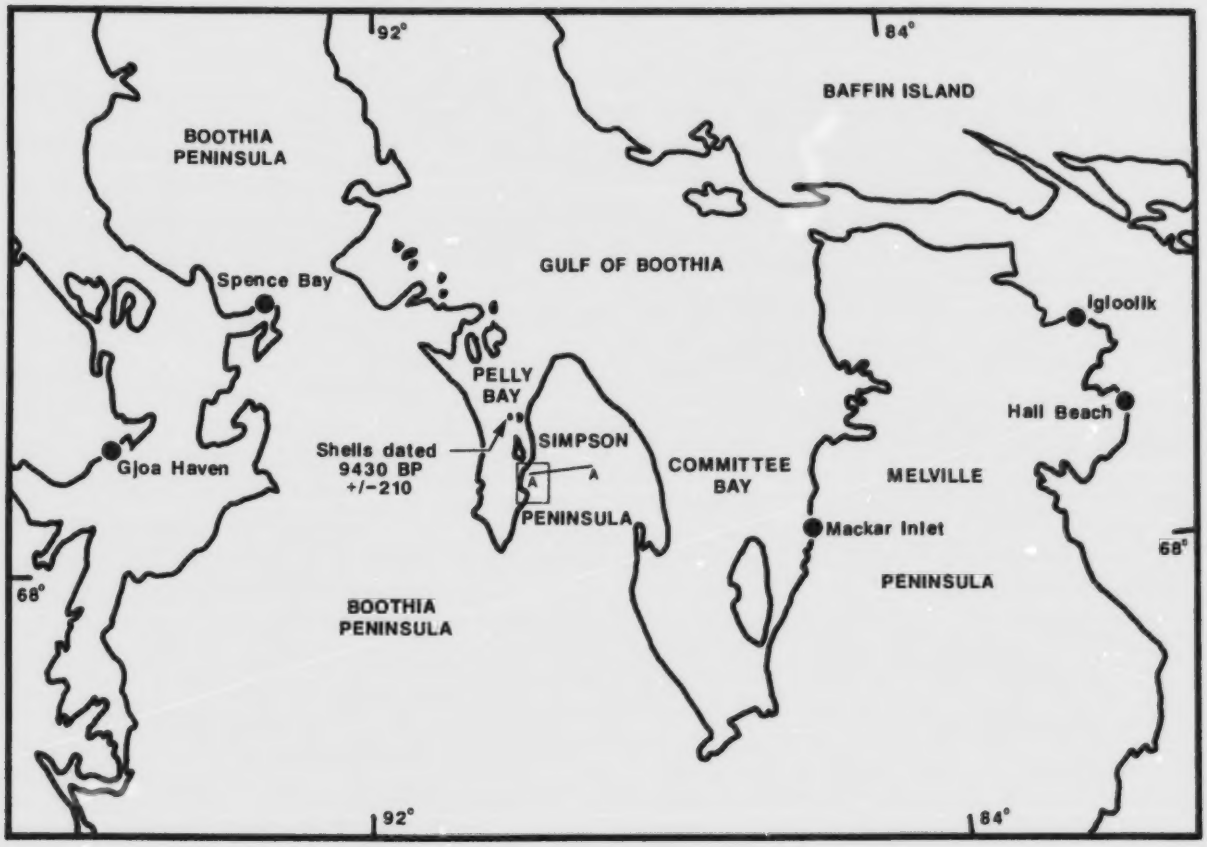


Figure 1. Part of Central Arctic showing location of the study area (outlined) and place names. Strandlines were surveyed along transect 'A-A'.

Knowing the marine limit for a study area, it is possible to construct a map showing the extent of land submergence. If a suitable land emergence curve is available, the post-glacial marine margin chronology can be established and mapped. Through such a series of maps, the pattern of Holocene land emergence becomes apparent. The greatest changes in coastal outline during the Holocene occurred in areas with considerable variation in relief over short distances, and where the marine limit is relatively high. In the selection of a study area, these criteria were considered along with its suitability for field reconnaissance of raised beaches and other evidence of former water-planes. The geomorphological evidence, if accurately surveyed by plane survey methods, could yield data on crustal upwarping and tilting, which in turn could enable inferences to be drawn about the pattern of deglaciation.

The analysis of survey data has commenced, and will be a lengthy undertaking. However, it has proven possible to map the Holocene marine margin chronology of the study area and to observe patterns of coastal change. This paper is, firstly, a preliminary report detailing investigative methodology and data collected during the 1986 field season. Secondly, it is a discussion of the pattern of land emergence along the western Simpson Peninsula, N.W.T., an area which illustrates well the magnitude of coastal changes in the Central Arctic. The discussion may be compared with previously published papers which deal mostly with areas in which the marine limit is lower or the topography is less varied. It was felt that there is a need for detailed studies of smaller areas, now made possible by the recent publication of small scale (1:50 000) maps of much of the Canadian Arctic; this is one such study.

The study area

The hamlet of Pelly Bay, N.W.T. (68°34'N, 89°51'W) is situated on the west coast of the Simpson Peninsula (Fig. 1). It was used as a logistics base for field camps along the west coast, in the neighbouring highlands, and in the central portion of the Peninsula. Although some data were collected farther afield, an area measuring 37 by 25 km (Fig. 2) was chosen for detailed treatment. This was because the loss of resolution, upon reduction of maps for printing, might otherwise make it difficult to visualise Holocene coastal changes. For discussion purposes, Fig. 2 has been divided into four areas whose unofficial names reflect their physiographic characteristics: Login Bay Peninsula, Login Bay Steps, Parke Hills, and Barrow Lake Steps. The areas are separated by valleys.

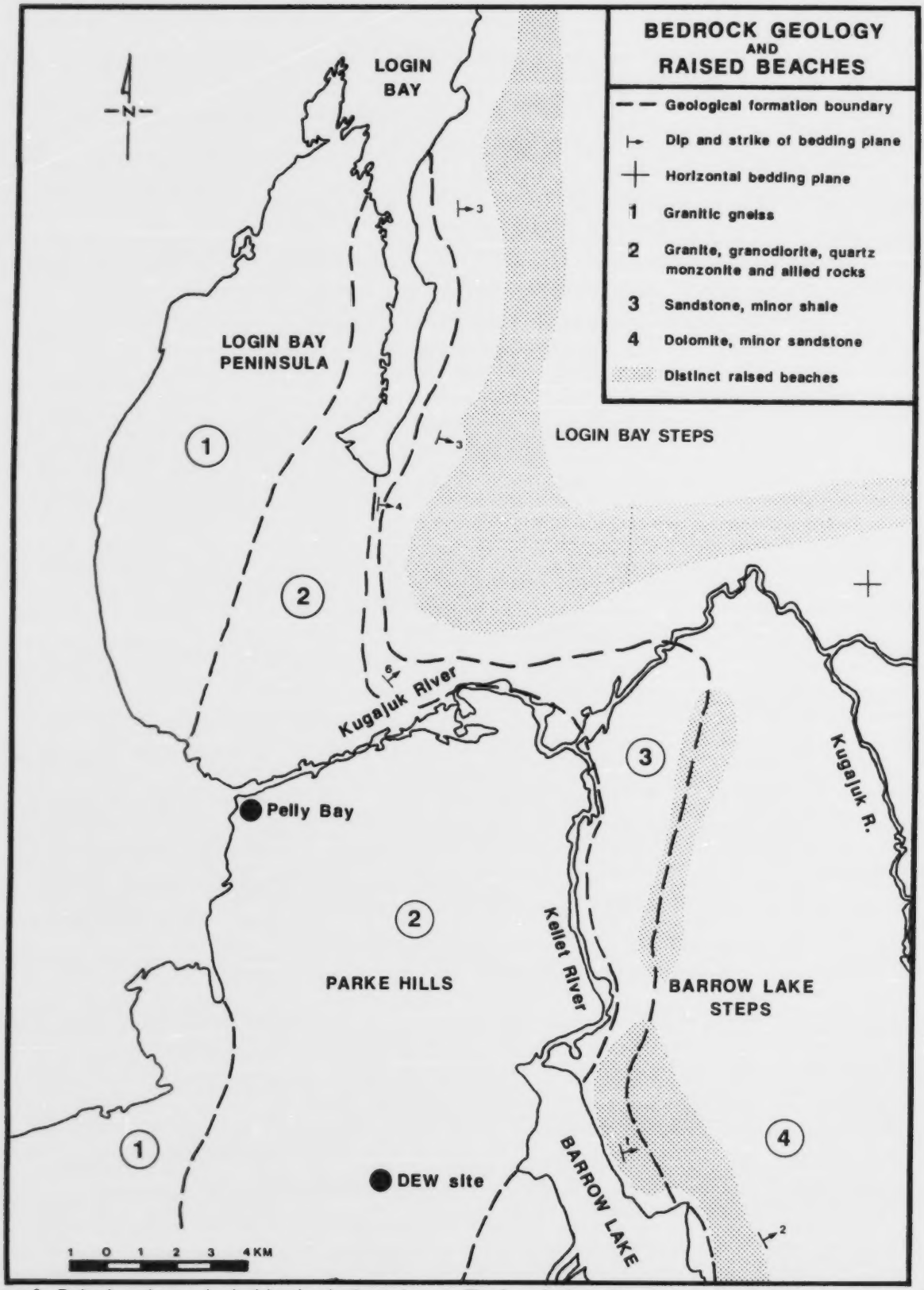


Figure 2. Bedrock geology and raised beaches in the study area. The four physiographic areas are shown. Extensive raised beach complexes exist east of Login Bay and continue eastwards, up to the marine limit approximately 20 km beyond the coverage of this map.

The Login Bay Peninsula and the Parke Hills consist of gneissic and granitic rocks of Archaean and/or Aphebian (early Proterozoic) age. These comprise part of the Wager Plateau, which belongs to the Boothia Uplift, the igneous-metamorphic spine of the Boothia Penninsula (Kerr, 1977). The Wager Plateau portion of the study area is rugged, with elevations up to 325 m. Till cover is discontinuous, and most till is exposed and clast-supported with locally derived boulders. There are some patches of immature soil, mostly depressional regosols, in places where boulder fields have been colonised by mosses. Cryosols are scarce, as is patterned ground. The highland surfaces are mostly exposed regolith and bedrock, whereas the lowlands around the settlement have a thick mantle of glaciofluvial and glaciomarine sediments. No evidence of raised beaches was found on aerial photographs, although traces were found during field work.

The Wager Plateau is flanked to the east by the sedimentary rocks of the Simpson Lowland, which dip away from it. A band of Ordovician sandstone separates the Precambrian plateau rocks from the Ordovician and Silurian dolomite forming most of the Simpson Lowland (Heywood, 1967). The Login Bay Steps and the Barrow Lake Steps lie on the Simpson Lowland. The lowland rocks are considerably less resistant than those of the plateau, accounting for the lower elevations and gentle slopes of the lowlands. They are mostly covered with a discontinuous till veneer 0.5–2 m thick, so the surface mimics the bedrock form. Thick, fluted till is occasionally found (Dyke, 1984). Cryosols occur over much of the lowlands, frequently on beds of glaciomarine silt. Fossil shells are often exposed by cryoturbation and are numerous at all elevations, particularly around ice-wedge cracks of patterned ground.

Extensive raised beach complexes exist on the Login Bay Steps, an area named after its terraced appearance. The sequence of gentle slopes and minor escarpments is rock-controlled, reflecting the bedding planes; the strike of the sedimentary strata is parallel to the coast, and near the bay the dip is 2–3° to the east, becoming horizontal a few kilometres inland. Glacial scour and fluvial processes probably were instrumental in producing the terracing, on which well developed beaches formed later. Significantly, many of these raised beaches are long enough for warping and tilting to be discerned above the error terms associated with survey measurements. Moreover, some are curved in plan, and have east-west as well as north-south trending segments, reducing the uncertainty in computing isobase direction and amount of tilt by the so-called 'triangle method' (Andrews, 1966). A few distinct relict strandlines also appear on the Barrow Lake Steps.

Within the area of Fig. 2 there are no long, well-preserved strandlines representative of the earlier parts of the emergence envelope. Consequently, it was necessary to survey selected beaches found along a transect east of Login Bay, close to the marine limit (Fig. 1). These data should contribute to a more complete picture of the pattern of ice retreat.

Method

The first stage of investigation was a reconnaissance by map and aerial photo to determine the distribution and location of geomorphic evidence suitable for survey. The locations of three high elevation shell beds, observed near the DEW station in 1980 by the writer, were marked on a 1:50 000 map. It became apparent that one bed lay above the 250 m contour, suggesting that the marine limit is higher than generally thought. It was decided to test this possibility by revisiting the site and calculating its exact elevation by levelling.

As many of the selected strandlines were far from the present coast, it was not always possible to establish reference elevations by levelling from observed mean sea level. It was decided that transferring zero datum by differential levelling would be possible only if a strandline lay within 3 km of the sea; beyond this, it would be difficult to maintain a cumulative error less than 1.0 m. Another method of elevation control, which could be employed over the entire study area, was therefore devised.

The National Geodetic Data Base lists one vertical control point (126.45 m) on the western Simpson Peninsula. Although 25 km NW of the settlement, on Helen Island (68°46′N, 89°59′W), it provides a reference for determining spot elevations by parallax bar. As the aluminium disc could not be identified on an aerial photo, a nearby flat spot was taken as an arbitrary datum. A visit to the spot enabled the elevation difference between the disc and the datum to be measured, so that corrections could be applied to parallax bar readings. Thus, the instrument was able to read spot elevations in m asl (1927 datum), probably to within the approximately 0.5 m tolerance to be expected with such a device. Spot elevations of prominent features were taken along 41 transects, so that to establish datum away from the sea, it was necessary only to level from one of 410 readily identifiable control points.

The accuracy of this method was tested by comparing parallax bar elevations against elevations referenced from the observed mean water plane. Seven arbitrary datum markers were emplaced along the coast 1–2 km apart. By taking simultaneous tide measurements at adjacent points, between highest tide and the nearest marker, water slope was calculated once the points had been joined by levelling (Marmer, 1951; British Admiralty, 1975). At a mid-point along the set of markers, mean sea level was determined with multiple observations at high and low tides, as outlined by Forrester (1983). The markers were then tied to the observed sea level datum by applying corrections.

Observed mean level was related to the 1927 datum by referencing the mid-point marker to a parallax bar control point. The observed mean was found to differ from the predicted parallax bar mean by only 0.38 m. It was decided not to correct for post-1927 sea level change because the 1927 datum is only an approximation of the geoid, based on a 1928 adjustment of mean water levels at the Halifax, Yarmouth, Pointe-au-Pere, Vancouver, and Prince Rupert gauging stations. Perturbations of the geoid, which cannot be realistically quantified, would probably invalidate a correction. Global sea level changes during this century have not, in any case, been large enough to warrant the effort involved in deriving such a questionable value. Nevertheless, the parallax bar method was demonstrated to be accurate for elevation control in water-plane analysis, but not accurate enough for surveying along strandlines.

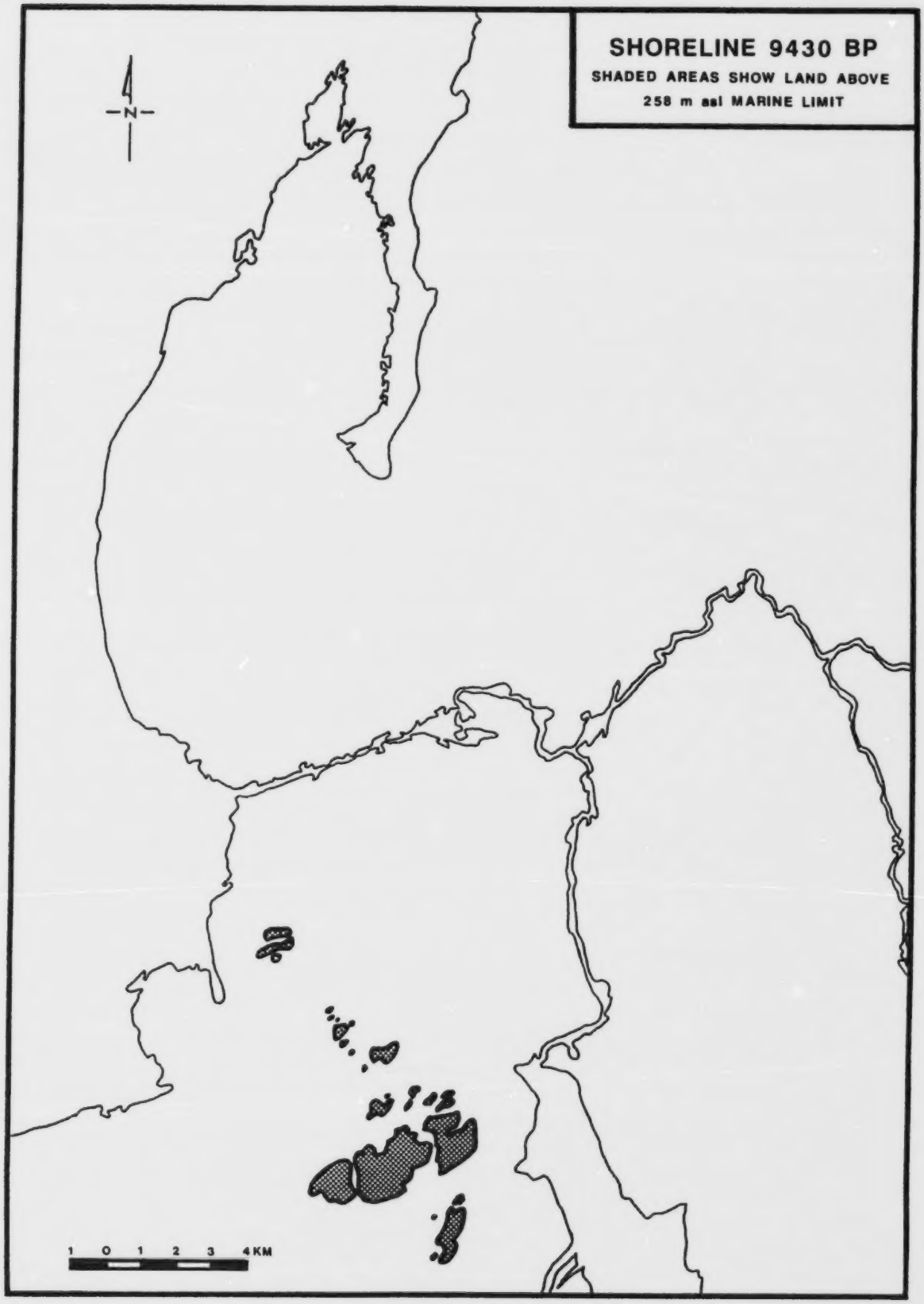


Figure 3. Land emergence immediately following deglaciation.

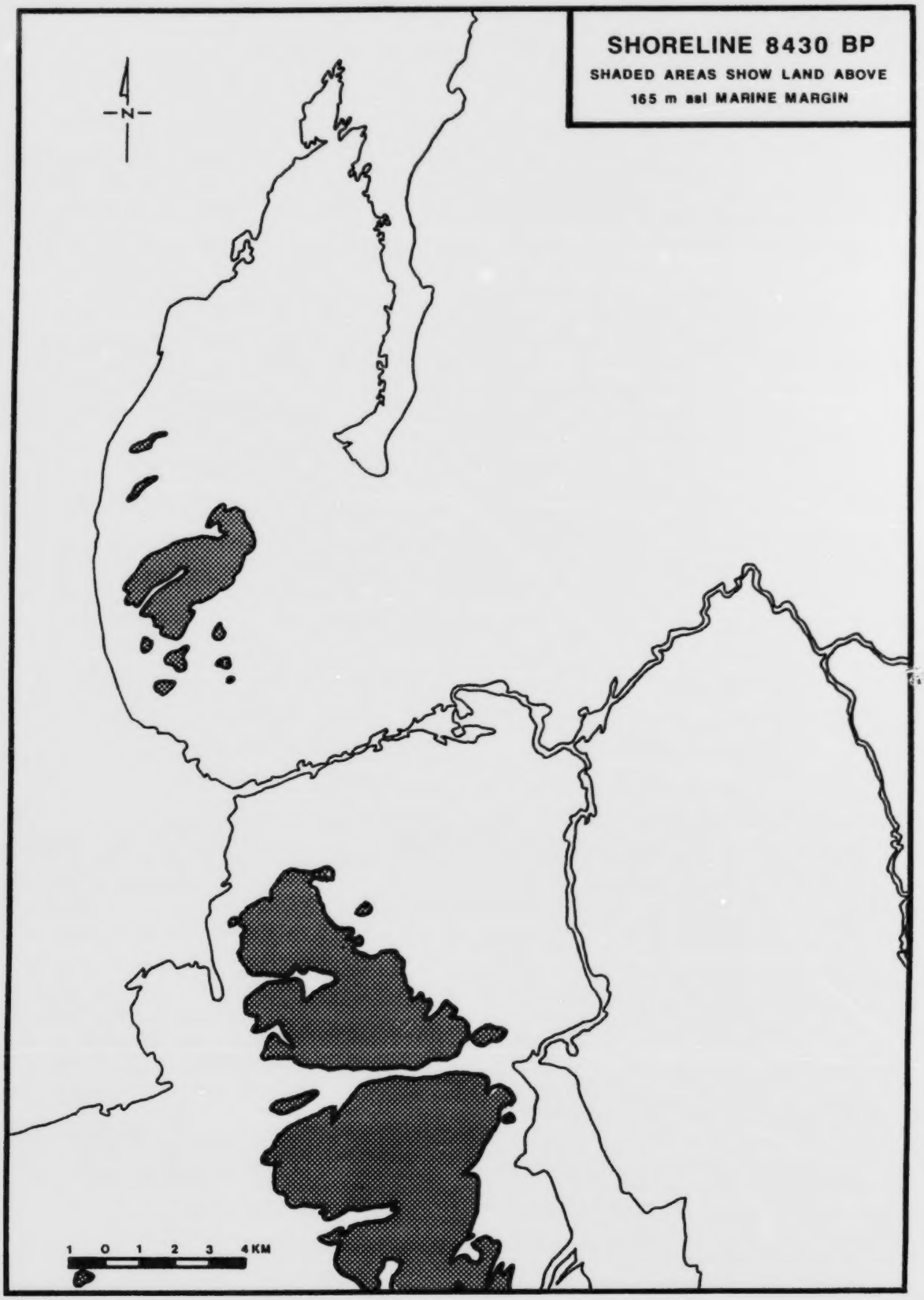


Figure 4. Land emergence 1000 years following deglaciation.

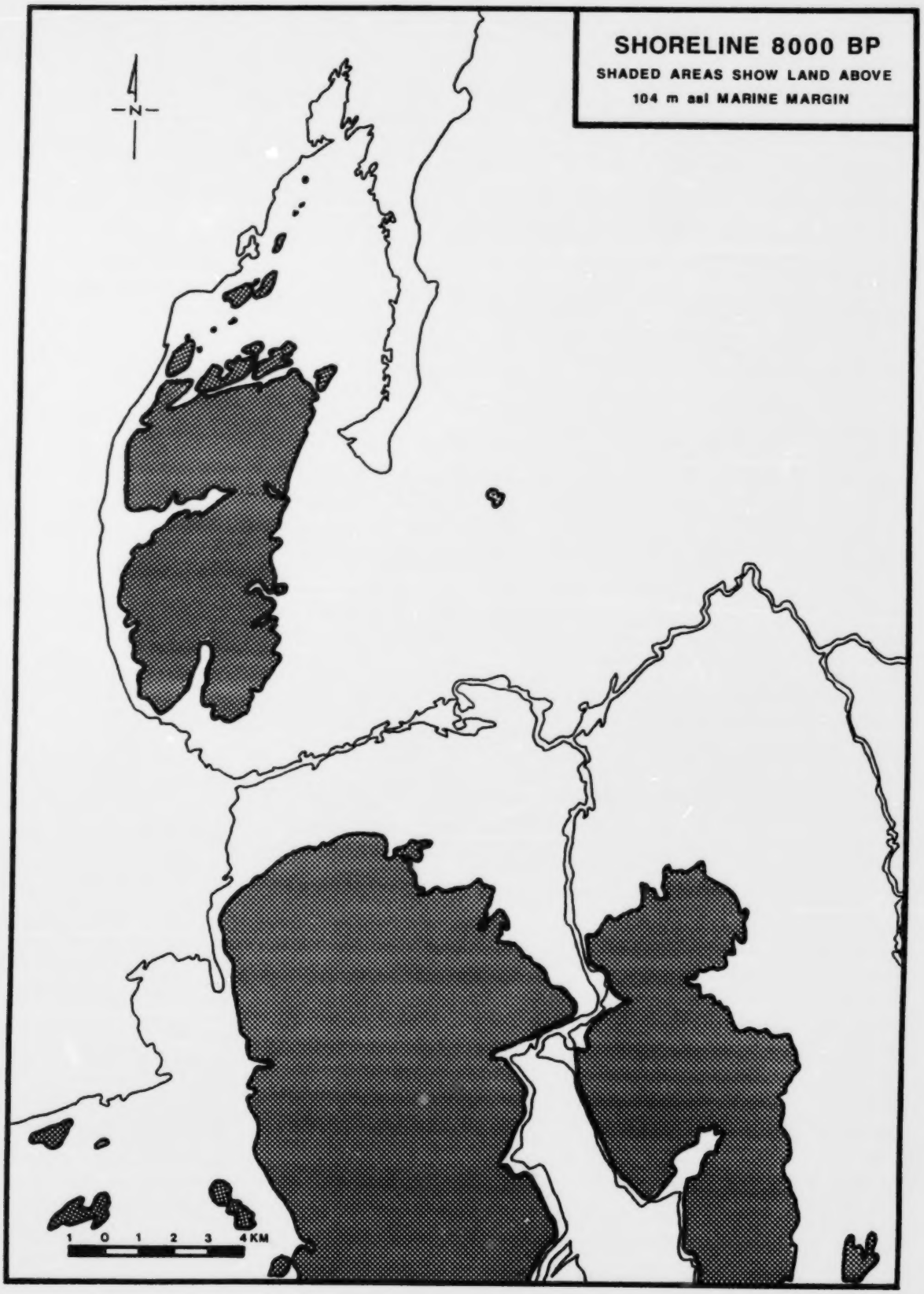


Figure 5. Land emergence at 8000 BP.

A transit was used to transfer elevations when horizontal sightings were above or below the stadia rod; that is, when a vertical circle reading had to be taken. This occurred primarily during levelling from a parallax bar control point to a strandline. The main exception was the establishment of correct elevation of the highest shell-bearing silt deposit in the Parke Hills. This entailed levelling from a known elevation at the DEW site across 4 km of rugged terrain. It was possible to use a level to survey along strandlines, greatly speeding up the work.

The techniques used in strandline survey were well-established ones (eg. Goldthwaite, 1908; Andrews 1966, 1970a). It is impossible to ascertain error of closure on a linear feature, so observations were based on one control point mid-way along each strandline. Multiple backsights were taken to minimise vertical error. The level's stadiametric range-finder and horizontal vernier were used to maintain horizontal control. Andrews (1970b) identified four sets of morphological features which can be used to define former water-planes: delta surfaces, boulder barricades, storm beaches, and wave-cut terraces. The latter were the most common in the study area, sometimes distinct and continuous for over 20 km. This is fortunate, for terraces can be measured to a comparatively high precision of perhaps +/−0.7 m (Robinson, 1908). This estimate may be too optimistic, but no other value has been noted in the literature.

Data from the strandline surveys consist of the following values for each observation: instrument height, vertical wire readings (three), horizontal angle, and English description. They will be entered into a data file, and the numerical values will be read and related to control elevations by a suitable programme. A second programme will perform multiple regression analyses to determine slopes and curvatures of the strandlines. It will also apply polynomial equations of various orders to determine the isobase direction and slope, according to Andrew's (1966) 'triangle method'. This should enable a best-fit isobase map to be produced; that is, a map with contour lines joining points of equal elevation and age. An isobase map gives a pictorial representation of differential crustal recovery, and can provide information on the pattern of deglaciation.

The isobase map will be used in conjunction with a series of land emergence maps. The latter depict the pattern of land emergence. The emergence curve for the central Boothia Peninsula given by Dyke (1983) has been used to assign ages to water-planes. Samples of fossil shells were taken at various elevations, for possible radiocarbon dating. These may be used to correct Dyke's regional curve to better represent emergence in the study area. The emergence maps were produced by tracing over 1:50 000 scale topographic maps using a light-table. Aerial photos also were used in mapping the marine margin. Such maps assume that uplift was uniform, ignoring differential crustal recovery. For a small study area, this assumption that the marine limit is synchronous (rather than diachronous) is valid; the maps remain useful tools for geomorphic analysis.

Discussion

During the deglaciation of the study area, the ice was in contact with the sea. Thus, over short distances, the date of deglaciation and formation of the marine limit were synchronous. Dyke (1983) dated shells from glaciomarine silt on Korvigduak Island (Fig. 1) at 9430 BP +/−210. From this he concluded that all of the Simpson Peninsula was free of the westward retreating ice by that time. However, the sample was taken at 225–230 m asl., well below the 240–250 m limit he identified from aerial photos, and farther below the 258 m limit determined in this study. The actual date of deglaciation was probably earlier. Assuming initial rebound of over 0.2 m/yr deduced from Dyke's emergence curve, it may have occurred more than a century before 9430 BP.

The pattern of ice-marginal features identifiable by aerial photography on the Simpson Peninsula indicates, for the most part, westward ice retreat. As the ice margin retreated into the area of Fig. 2, it began to rotate such that the direction of retreat became southward. An east-west end moraine and several DeGeer moraines at the foot of the Parke Hills, south of the settlement, show that the margin was retreating south at that point. From this it can be concluded that the marine limit near the DEW site is younger than 9430 BP. Using Dyke's figure for local rate of ice retreat of 100 m/yr, it would seem that the DEW site location was deglaciated at least a few decades after 9430 BP.

Figures 3–7 depict the extent of marine inundation at different times in the Holocene. They were drawn on a light table, over 1:50 000 scale topographic maps. The regional emergence curve in Dyke (1983) was used to assign sea level to specific times. The maps do not take into account isobase curvature and tilt, as the marine margins tend to follow present contour lines. The minor deviations present resulted from corrections on the basis of aerial photography. Nevertheless, the trend of land emergence can be discerned.

Figure 3 has the marine limit at 258 m asl, the highest surveyed elevation of shell-bearing sediments. Dyke's curve does not include elevations over 240–250 m asl. The extent of inundation is even more striking when considered on a regional scale; the only other dry land was a few high peaks just south of the study area and some about 50 km east. The amount of postglacial recovery at the surveyed marine limit would be approximately 288 m, assuming that 30 m of meltwater remained to be added to the oceans since formation of the marine limit.

Weertman (1961) expressed crustal displacement at equilibrium as the ratio between the density of the ice load and that of the asthenosphere. Ice has about 0.3 times the density of asthenosphere, so around 330 m of rebound can be expected for each kilometre of ice cover. Hughes *et al.* (1981) used this ratio, and the assumption that equilibrium was reached at 17 000 BP, in their reconstructions of maximum ice thickness and crustal displacement. They calculated that ice over the study area was 2400 m thick, and that displacement was 740 m. It would seem, then, that nearly two thirds of total recovery (492 m) had taken place prior to deglaciation.

One thousand years after deglaciation, relative sea level had fallen to 165 m, meaning that about two-thirds of total postglacial recovery had already occurred (Fig. 4). This indicates an average rate of uplift of over 0.1 m/yr during that period. It was certainly much greater immediately following deglaciation. The scarcity of strandline evidence at and near the marine limit is probably related to the short lifetimes of

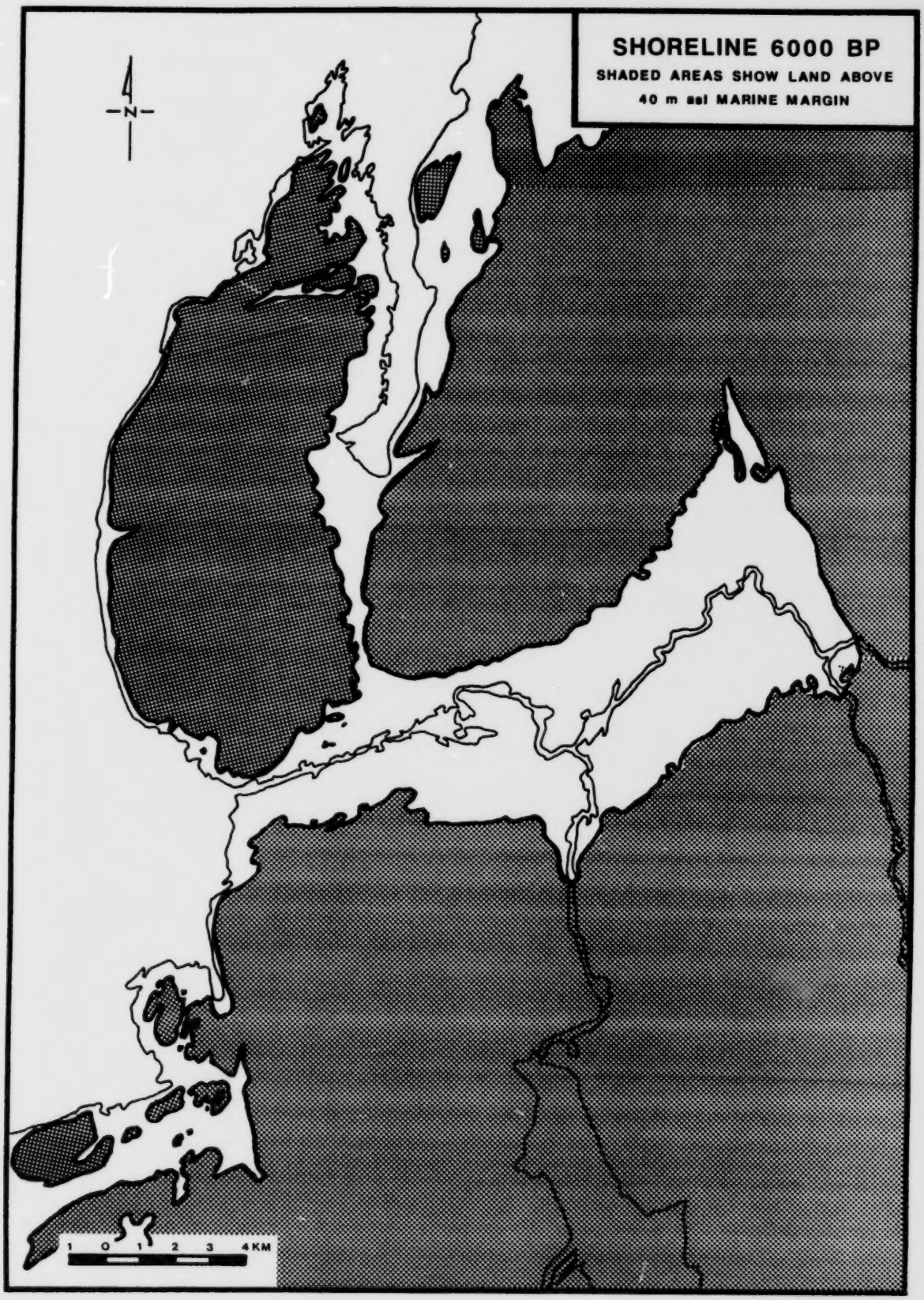


Figure 6. Land emergence at 6000 BP.

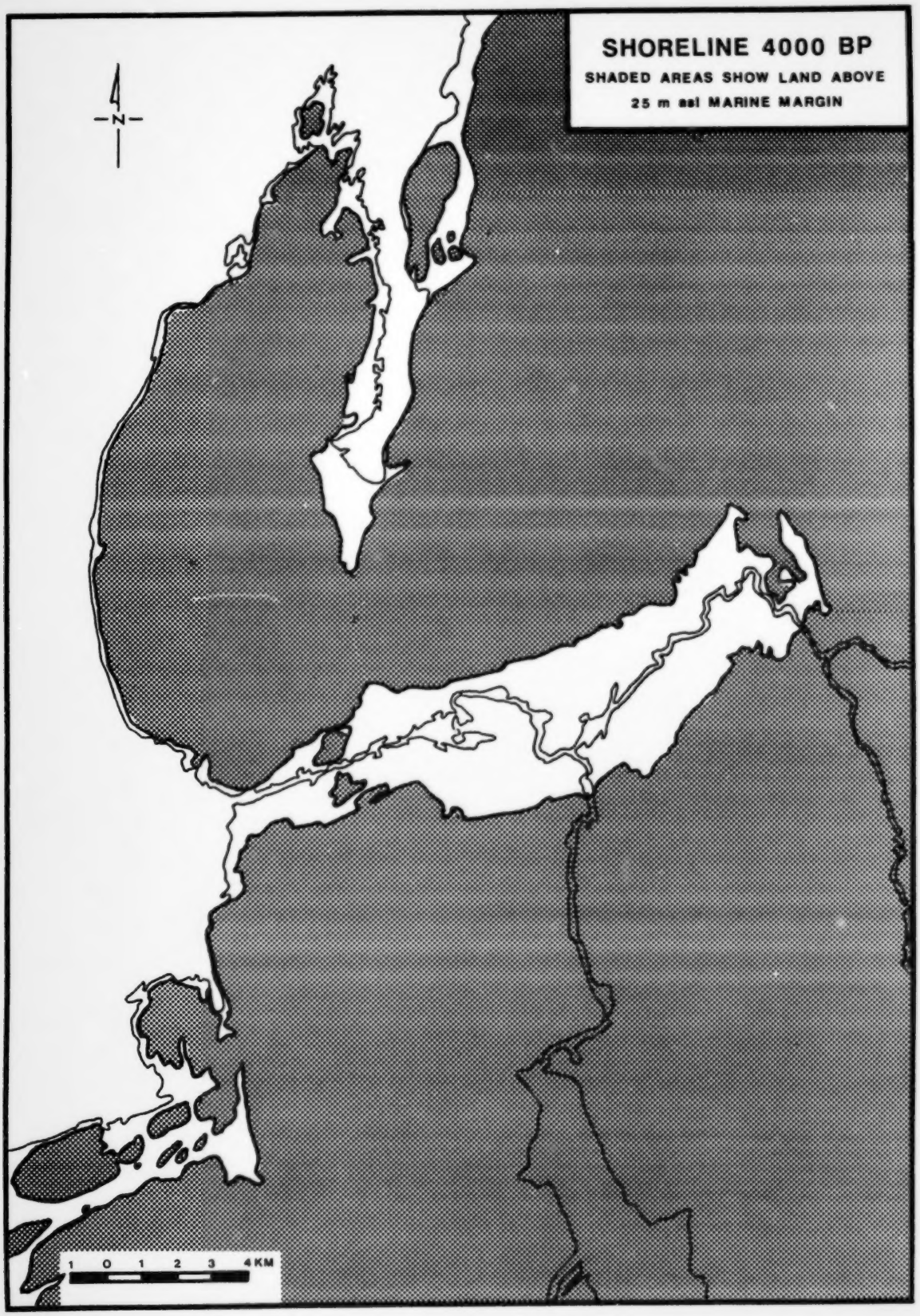


Figure 7. Land emergence at 4000 BP.

high water planes. The rate of emergence appears often to have exceeded the ability of the wave energy regime to produce distinct beach forms. During this interval, many of the small islands at maximum sea stand had coalesced. As valleys and cols were exposed, digitate shorelines developed. Nearshore and onshore slopes were steep owing to the comparative ruggedness of the higher lands. Horizontal shoreline displacement was therefore minimal, despite emergence of 93 m.

By 8000 BP, three major islands dominated the area (Fig. 5). In the preceding half-millennium, sea level had declined by about 60 m. Emergence continued to expose gentler gradients, hastening the coalescence of islands and producing a coastal environment more conducive to longshore transport and the formation of accretionary beach features. The rapid emergence of the Login Bay Steps began soon after this date, and was largely complete by 6000 BP (Fig. 6). Offshore gradients of less than 1% over distances in excess of several hundred metres were common on the Steps, so horizontal tidal movement was well over 100 m in places, far greater than the 10–20 m common today. Wide relict tidal mudflats (0.5–1.5 m thick) survive between 40–50 m, and are attributable to the former shoaling conditions. Approximately 75% of total emergence had occurred by 7000 BP, by which time sea level stood between the 50 and 60 m contours. The majority of beach sequences are found above this level, and must have been formed during the upper 75% of the emergence envelope.

Some of what appear on aerial photos to be raised beaches 30–50 m asl, and paralleling Login Bay, were found to be rock-controlled ridges with thin shingle mantles, Averaging 2–3 m high, they follow the strike of the bedrock, and were responsible for a number of lagoons as the sea retreated. The discontinuous ridges became spits which sometimes joined the shore to the south. In such cases they acted as groynes, trapping longshore sediments from the north and causing observable beach starvation to the south.

By 6000 BP (Fig. 6), the Kugajuk valley was an elongated, narrow-mouthed bay into which the Kellet River drained from Barrow Lake. The lake itself ceased to be a bay about 7800 BP. The Kugajuk Valley is very low-lying, most of the floor being below 10 m asl. There was little change in the shore of the submerged valley between 6000–2000 BP (Figs. 6–8). Shortly after 2000 BP sea level fell below 10 m and the valley floor became an immense tidal flat, draining very quickly just before 1000 BP. The flatness of the surface suggests that the front of the rising tide may have propagated up the valley as a bore; the water was probably unable to spread evenly over the vast shallows fast enough to match the rise at the tidal entrance. Today, the tide causes a rise in river level as far as 7 km inland, but the river's outline changes little in plan because the bed follows a trough in the valley floor.

Login Bay formed around 5850 BP, with the closing of the strait leading into the submerged Kugajuk valley. They bay's retreat to the north has averaged 0.8 m/gr since the strait was closed. Although the bathymetry of Login Bay has not been recorded, the strike and dip of the bedrock imply that the uniform linear slope at the bay's head continues for some distance offshore. No figure for residual uplift in the area has been published, but 0.2–0.3 cm/yr as a conservative estimate would probably not be far off. At this slow rate and given the steepness of most present-day shore slopes, the shoreline in the study area is retreating very slowly except at the head of Login Bay.

Summary

Through the series of land emergence maps presented in this paper, it has been possible to establish the approximate marine margin chronology. These maps assume uniform uplift across the study area, and thus indicate nothing of the pattern of deglaciation. They are, however, accurate enough for discussion purposes. The strandlines surveyed are long and distinct, and were formed across most of the emergence envelope. In addition, they are dispersed over a wide area and are often curved. These conditions are required for the production of an isobase map by Andrew's 'triangle method'. The isobase map will permit inferences about the pattern of deglaciation to be made and to be tested against geologic evidence. Moreover, the isobase map will enable the land emergence maps to be redrawn with greater precision. In particular, it may prove possible to map the deglacial, as well as the post-glacial, marine margin chronology.

Acknowledgments

The field research was made possible by grants from the Northern Scientific Training Programme (Department of Indian and Northern Affairs) and the Royal Canadian Geographical Society. Chlorophylle Haute Technologie Ltée. provided harsh weather clothing and equipment for the project. The U.S. Air Force extended its hospitality at the Pelly Bay DEW site, offering meals and lodgings during a period of inclement weather. The assistance of Professors J.G. Cosley and J. Bednarski, both of the Trent Geography Department, in proof-reading the manuscript, is much appreciated. Particular thanks are due to field research assistant Ian Shearer, who cheerfully endured unusually cold and wet arctic field conditions.

References

Andrews, J.T. 1966. Pattern of coastal uplift and deglacierization: West Baffin Island, Northwest Territories, Canada. Geographical Bulletin 8:174–193.

Andrews, J.T. 1970a. Differential crustal recovery and glacial chronology (6700 to 0 BP), West Baffin Island, N.W.T. Canada Arctic and Alpine Research 2:115–134.

Andrews, J.T. 1970b. A geomorphological study of post-glacial uplift with particular reference to Arctic Canada. Special Publication No. 2. Institute of British Geographers, London. 156 p.

Andrews, J.T. 1975. Glacial systems: an approach to glaciers and their environments. North Scituate, Massachusetts: Duxbury Press. 191 p.

British Admiralty. 1975. Datums for hydrographic surveys. Admiralty Tidal Handbook No. 2. London: H.M. Stationary Office. 38 p.

Bryson, R.A., Wendland, W.M., Ives, J.D., and Andrews, J.T. 1969. Radiocarbon isochrones on the disintegration of the Laurentide Ice Sheet. Arctic and Alpine Research 1:1–14.

Clark, J.A., Farrell, W.E., and Peltier, W.R. 1978. Global changes in post-glacial sea level: a numerical calculation. Quaternary Research 9:265–287.

Dyke, A.S. 1983. Quaternary geology of Boothia Peninsula and Northern District of Keewatin, Central Canadian Arctic. Memoir No. 407. Geological Survey of Canada, Ottawa. 26 p.

Forrester, W.D. 1983. Canadian tidal manual. Ottawa: Department of Fisheries and Oceans. 138 p.

Goldthwaite, J.W. 1908. A reconstruction of water planes of the extinct glacial lakes in the Lake Michigan Basin. Journal of Geology 16:459–476.

Heywood, W.W. 1967. Geological notes Northern District of Keewatin and Southern Melville Peninsula, District of Franklin, Northwest Territories. Paper No. 66–40. Geological Survey of Canada, Ottawa. 20 p.

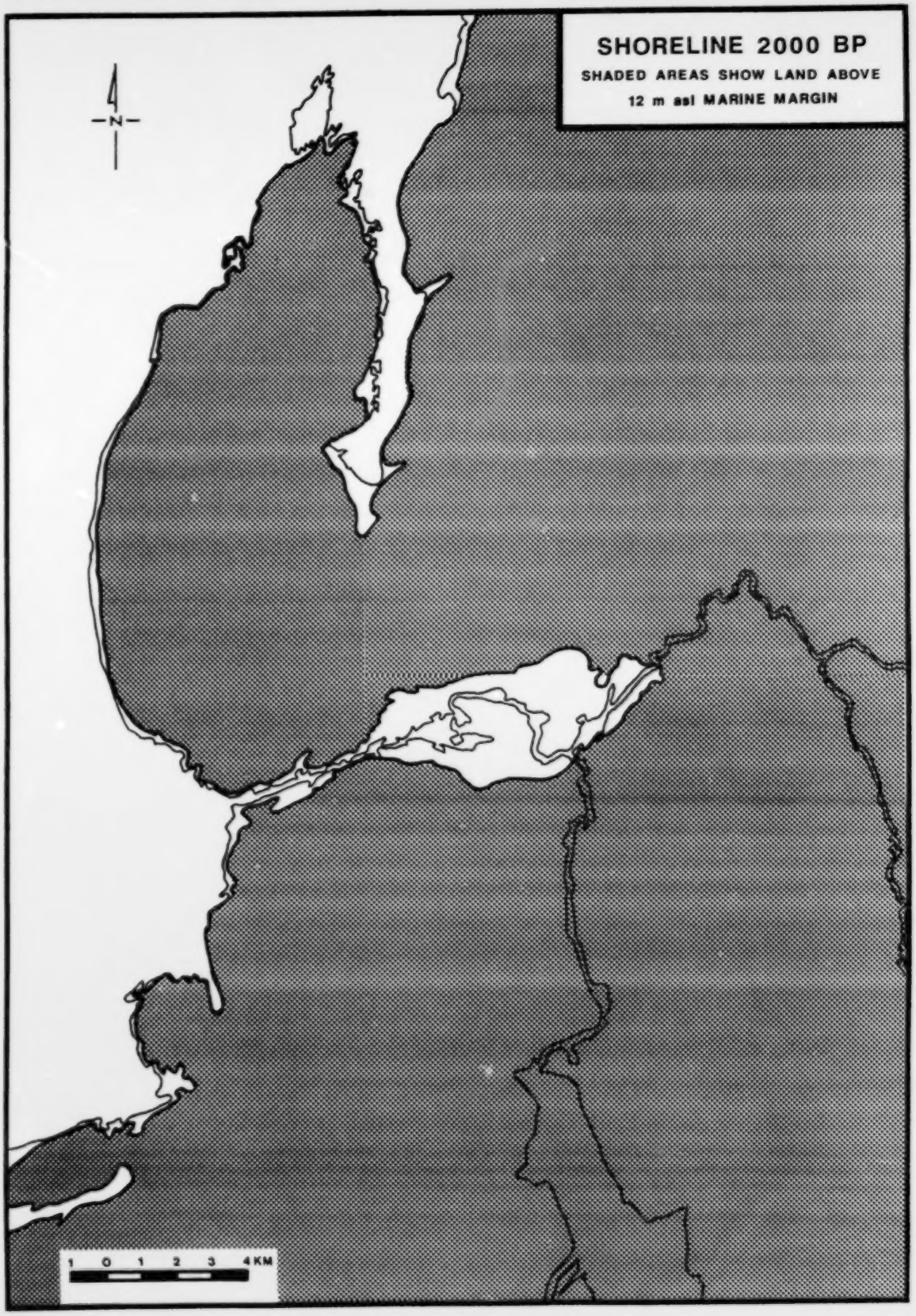


Figure 8. Land emergence at 2000 BP.

Hughes, T.J., Denton, G.H., Anderson, B.G. Schilling, D.H., Fastook, J.L., and Lingle, C.S. The last great ice sheets: a global view. In: Denton, G.H., and Hughes, T.J., eds. The Last Great Ice Sheets. New York: John Wiley and Sons. 275-317.

Ives, J.D., Andrews, J.T., and Barry, R.G. 1975. Growth and decay of the Laurentide Ice Sheet with comparisons with Fenno-Scandinavia. Naturwissenschaften 62:118-125.

Kerr, J.W. 1977. Structural geology of Somerset Island and Boothia Peninsula, District of Franklin. In: Report of Activities, Geological Survey of Canada. Paper No. 77-1A. Ottawa: Geological Survey of Canada. p. 107-111.

Marmer, H.A. 1951. Tidal Datum Planes. U.S. National Ocean Survey Special Publication No. 135. Washington: U.S. Government Printing Office. 142 p.

Mayewski, P.A., Denton, G.H., and Hughes, T.J. 1981. Late Wisconsin ice sheets in North America. In: Denton, G.H., and Hughes, T.J., eds. The Last Great Ice Sheets. New York: John Wiley and Sons. 67-178.

Moran, J.N., and Bryson, R.A. 1969. The contribution of the Laurentide ice wastage to the eustatic rise of sea level 10 000 to 6000 B.P. Arctic and Alpine Research 1:94-104.

Morner, N-A, 1969. The late Quaternary history of the Kattesat Sea and the Swedish main coast. Sveriges Geologiska Underskokning Series C, N.R. 640, Arsbok 63, N.R. 3.

Peltier, W.R. 1982. Dynamics of the ice age earth. Advances in Geophysics 24:1-146.

Robinson, H.H. 1908. Ancient water planes and crustal deformation. Journal of Geology 16:347-356.

Shepard, F.P. 1963. Thirty-five thousand years of sea level. In: Clements, T. ed. Essays in Marine Geology in Honour of K.O. Emery. Los Angeles: University of Southern California Press. 1-10.

Walcott, R.I. 1972. Past sea levels, eustasy, and deformation of the earth. Quaternary Research 2:1-14.

Weertman, J. 1961. Equlibrium profile of ice caps. Journal of Glaciology 3:33-38.

THE RECONSTRUCTION OF PALEOENVIRONMENTAL CHANGES IN TRUELOVE LOWLAND, DEVON ISLAND, N.W.T

Robert B. Young, Peter Kelly, Andrew Heyes, Kim Law and Roger H. King

Department of Geography, University of Western Ontario, London, Ontario N6A 5C2

Level: R. Young, Master's

Abstract

An investigation of the paleoenvironmental record preserved in the surficial sediments in Truelove Lowland, Devon Island, N.W.T. is presently underway. Glacio-isostatic rebound over the last 20,000 years has resulted in an emerged coastal lowland containing a number of large lakes separated by a sequence of raised beaches. Isochrones based on precisely determined height and radiometric age determinations of the beaches depict the progressive emergence of the Lowland from the sea over time. Holocene soil development on these beaches is being studied through an analysis of variance of the soil physical, chemical and site characteristics.

In places, the progressive accumulation of organic and inorganic sediments within the lakes has led to the formation of ice-cored palsa when the lakes were uplifted and drained. Cores have been obtained using an ice-corer from two palsa in the Lowland and one palsa in the Truelove Valley with a basal date of 6,900 ± 115 years B.P. Lacustrine sediment cores have also been obtained using a modified Livingstone piston corer from four large lakes in the Truelove Lowland and one lake on the interior plateau to the east of the Lowland. The record of Holocene paleoenvironmental changes preserved in these sediments is being examined through an investigation of the pollen spectra and sediment geochemistry. It is believed that the soils and former lacustrine sediments contain a record of much of the environmental change that has occurred within the coastal lowlands during the Holocene.

Key words: Holocene, glacio-isostasy, postglacial emergence, soil development, pollen analysis, lacustrine sediments, palsa, geochemistry.

Résumé

Truelove Lowland (lat. 75°33′N., long. 84°40′O.), dans l'île Devon est une oasis de l'Extrême-Arctique qui a été soumise à un relèvement isostatique depuis 10 000 ans. Il en résulte que ces basses-terres sont parsemée d'une série de plages suspendues, séparées par des prés humides et des lacs qui représentent d'anciennes zones littorales. L'auteur a utilisé les données géochimiques et les diatomées observées dans les sédiments lacustres à différentes hauteurs pour reconstituer l'évolution de l'oasis arctique. Les diatomées permettront de délimiter la zone de transition entre eaux saumâtres et douces, et toute transgression marine ultérieure. L'abondance relative des éléments chimiques contenus dans les sédiments permettra d'identifier les milieux d'érosion (K, Na, Al, Ti), le lessivage des sols (C1, B) et la productivité des organismes vivants (Si, Mn, Fe biogènes).

L'auteur a échantillonné cinq lacs de la région des basses-terres. Il a prélevé des carottes du fond des lacs par des trous percés dans la nappe de glace qui les recouvre. Les sédiments prélevés ont été démoulés et divisés en unités de 20 cm. La longueur moyenne des carottes était de 65,5 cm. Une subdivision ultérieure en sous-unités de 2 cm a été effectuée au camp de base avant transport, pour éviter la désagrégation des échantillons.

Mots-clés: Truelove Lowland, lacs de l'Extrême-Arctique, reconstitution du paléoenvironnement, diatomées, données géochimiques.

Introduction

Devon Island is the southeasternmost island of the Queen Elizabeth Islands in the Canadian Arctic Archipelago. On the northeastern coast of Devon Island there is a series of coastal lowlands, of which Truelove Lowland with an area

of approximately 43 km^2 is the westernmost. Under present environmental conditions the lowlands support a greater biological diversity and productivity than the surrounding lands (Bliss, 1977, 1). During the 1985 and 1986 summer field seasons, studies were initiated of the nature of the paleoenvironmental record preserved in the surficial deposits in Truelove Lowland. The primary objective of these investigations is a reconstruction of past environmental changes in the Lowland in comparison with the present conditions. This paper reviews the results of the two field seasons and the methodology being used to assess the nature of paleoenvironmental changes.

The coastal lowlands of northeastern Devon Island are the result of postglacial isostatic rebound following the retreat of the last Pleistocene glacial ice. Most of Truelove Lowland is covered with gravelly Quaternary deposits, largely in the form of a flight of raised beaches which, together with associated deposits, overlay a Precambrian basement complex of granulites and granitic gneisses. Dolomites and other sedimentary rocks of probable Cambrian age outcrop in places in the Lowland and form the >200 m cliffs to the east of the Lowland.

Previous studies have shown that the beaches were formed as a result of a postglacial marine regression consequent to the glacio-isostatic uplift (Muller and Barr, 1966; King, 1969; Barr, 1971; King, 1974). The beaches are composed of poorly stratified sands and gravel derived from the dolomites, limestones, sandstones, granulites and granitic gneisses that outcrop locally. As a result of the postglacial coastal emergence of the Lowland, a number of lagoons were isolated from the sea by off-shore bars which later constituted the raised beaches. These lagoons subsequently formed shallow lakes covering approximately 22% of the Lowland. Some of these lakes have since been filled with sediments to form meadows. The larger lakes, Phalarope Lake (155 ha), Fish Lake (101 ha), Immerk Lake (96 ha) and Loon Lake (16 ha), are relatively deep (7.0–8.5 m) with a mean depth of approximately 3 m (Bliss, 1977).

The present vegetation in the Lowland comprises a complex mosaic of sedgemoss meadows, cushion plant communities on the raised beaches, and dwarf shrub heath in the rock outcrops. The surface of the interior plateau adjacent to the Lowland is a Polar Desert and more typical of the High Arctic in general. The Truelove Lowland flora includes 96 species of vascular plants, 132 species of mosses, 30 hepatics, 182 lichen species, and 92 species of fungi (Bliss, 1977). This vegetative cover provides an adequate food base for muskox, lemming, waterfowl, and associated predators. The diversity and productivity of the Lowland are unusual for this latitude and are the result of a special set of environmental conditions.

Holocene isostatic rebound

Previous research has shown that the postglacial marine limit in the Lowland lies at an elevation of approximately 76 m, dating to approximately 9,450 year B.P. (King, 1969; Barr, 1971). Corrected for the postglacial eustatic rise of sea level, the computed total glacio-isostatic uplift for the area is 107 m. During the first 2,500 years, isostatic uplift averaged approximately 2.5 m 100 $years^{-1}$ decelerating rapidly, with approximately 0.2 m 100 m $years^{-1}$ taking place over the last 7,450 years. At present isostatic equilibrium appears to have been attained, with glacio-isostatic uplift approximately matching eustatic sea level changes.

Fieldwork during the summers of 1985 and 1986 involved an extensive surface reconnaissance along the raised beach ridges in the Truelove Lowland and the areas immediately seaward and landward of the beach ridges. During this survey a number of whalebone samples were collected. The search for whalebone was especially concentrated in the elevational zone between 8 m and 50 m.a.s.l. where previous accurate control on the age of the beaches had been lacking. Several samples of whalebone from this zone were obtained and presently await ^{14}C dating. In addition, a Bowhead whale rib collected in 1985 near the upper marine limit at an elevation of approximately 62 m yielded a date of 8,920 $\pm$ 140 years (Beta-14819). During the 1986 field season more precise determinations were also made of the height of the marine limit at the base of the escarpment to the east of the Lowland.

Holocene emergence of the coastal Lowlands

Due to the postglacial emergence of the coastal lowlands the raised beaches in the Truelove Lowland differ considerably in age and elevation. Consequently, the Lowland's postglacial emergence history can be reconstructed in the form of a series of isochrones which delimit successive areas of emergence. King (1974) previously attempted such a reconstruction, with isochrones being constructed at approximaely 500 year intervals. However, the absence of an accurate topographic survey of the Lowland at that time precluded the construction of an isochrone map containing information on all of the major beaches. Consequently, during the 1986 field season a precise levelling survey was undertaken of all the raised beaches in the Truelove Lowland (Law, 1986). The datum point used in this survey was a fixed position at the Arctic Institute of North America (A.I.N.A.) Base Camp. All traverses were closed and all beach ridges of regional significance were included in more than one traverse. In addition, a number of reference survey pins established in preparation for the creation of a base map of the Lowland from stereo-orthophotographs were also included in the survey traverses. The established elevations of these pins will be used to correct the levelling data. The final result of this survey will be the creation of an isochrone map of the Lowland at a scale of approximately 1:15,000 which includes all the major raised beaches.

Soil development on the raised beaches

The raised beach sequence in Truelove Lowland supports a series of soils whose ages are related to the age of the beaches. Given that each beach in the lowland is of a different age, one can assume that this pedogenic series represents a chronosequence and therefore, by analyzing the soil physical and chemical properties within each beach, it should be possible to develop a chronology of soil development for this particular area of the Canadian Arctic Archipelago (Kelly, 1986).

The concept of the chronosequence principally evolved out of the work of Hans Jenny in the 1940's who stated that it is possible to have a series of soils where the properties that define it are functions of time with the variables of climate,

organisms, relief and parent material remaining constant (Jenny, 1941). The selection of soils along a time sequence presupposes that adjacent members of the sequence have at one time passed through, and been identified with the developmental stages represented by all preceding members (Stevens and Walker, 1970).

One problem with the chronosequence concept that becomes apparent with the raised beach sequence in Truelove Lowland is that it is very difficult to prove that all other factors except time have remained constant during soil development. However, although one can never prove that a soil series is a "true" chronosequence, it is possible to show that variation over time has been minimal if not insignificant through a detailed study of the individual pedogenic state factors. In this study a comprehensive random sampling design has been employed to facilitate the determination of variances in chemical properties attributable to differences in the age of the sites, and in depth, together with variances on individual beaches.

In the summers of 1985 and 1986, the raised beach sequence in the Truelove Lowland was extensively sampled and a large number of soil samples were collected according to a random sampling design that was rigidly adhered to. The sampling design was similar to that used by Sondheim and Standish (1983) in their study of a soil chronosequence in the forefield of the Robson Glacier, British Columbia.

In the Truelove Lowland, soil samples were collected from a series of raised beaches along two transects stretching from the present shoreline to the postglacial marine limit. A total of 24 beach ridges were sampled; 17 from a central transect nearly 5.5 km in length and another seven from a shorter transect towards the northern end of the Lowland. Four minor inspection pits were excavated on each beach and soil samples obtained at depths of 5–10 cm, 15–20 cm and 25–30 cm from each soil, producing a total of 12 samples from each beach, 288 samples in total. The locations of the sampling sites on each beach were determined using a random numbers draw representing distance from a central location. The sampling sites were located where the transect crossed the beach and at a distance to the north and south ranging between one and 30 m. The foruth site was similarly located but could be either north or south of the central transect point.

Each soil sample is presently being analyzed in duplicate for pH, Total Nitrogen, Total Phosphorus, Total Organic Carbon, pyrophosphate-extractable Fe and Al, dithionite-extractable Fe and Al, ammonium oxalate-extractable Fe and Al, cation exchange capacity, exchangeable Ca^{++}, Mg^{++}, Na^{+} and K^{+}, and total sand, silt and clay content. It is felt that these properties will best represent the processes which are likely to take place in a High Arctic environment, namely those of humidification, organic matter accumulation and incipient podzolization.

A statistical analysis of the soil data base will be conducted subsequently. In particular, it is proposed to employ an analysis of variance technique to provide a measure of the variance of individual soil properties between beach ridges and between soils on individual beaches. Nonlinear curve fitting techniques will be used on selected properties to determine the principal pedogenic processes acting on the beaches and to determine the variation of individual soil properties with depth. A principal components analysis, similar to that used by Mellor (1984) will also be employed to isolate these processes.

Paleolimnology

The lakes behind beach ridges in Truelove Lowland are assumed to have formed by a mechanism suggested by Rose (1981), who proposed that as isostatic rebound continues, the basin immediately behind the newly forming beach slowly becomes isolated from the marine environment. The basin which began as a littoral zone becomes a tidal pool which, in turn, becomes a small lake. Since each stage in the sequence is characterized by a change in the composition of the water, the nature of the sediments deposited will change both biologically, as indicated by diatom assemblage, and chemically, as indicated in the relative abundance of certain chemical elements. The resulting fresh water lake will also contain a variable sedimentary record which reflects the history of the lake's drainage basin. Using the vertical distribution of chemical elements in conjunction with the diatom assemblage in the sediments, it may be possible to describe the environmental history of an area immediately surrounding a lake (Young, 1986).

The objectives of this part of the project are to determine if lake sediments in Truelove Lowland reflect environmental changes in the drainage basin and to use lake sediments to reconstruct the post-emergence environment of a lake's drainage basin in order to make generalizations concerning Truelove Lowland.

During the 1986 field season the sediments of four lowland lakes and one lake located on the interior plateau (Lake Titty) were sampled. The lakes were sampled at their deepest points to negate the effect of ice scour on the surficial sediments. Davis (1968) has demonstrated that the most useful place to sample lake sediments is in the deepest part of the lake basin where distortion produced by disturbance and redeposition is least. The Lowland lakes are considered to be ideal for paleolimnological and local environmental reconstruction since they have not been disturbed by human activity and their respective drainage basins are small enough that anomalous features can be accounted and controlled for. The lake on the interior plateau will serve as an excellent regional pollen trap since it has a small closed drainage basin and minor local pollen influx.

Cores were taken with a modified Livingstone corer with an internal diameter of approximately 5.74 cm from a lake ice platform in late June, 1986. The sediment was extruded from the corer barrel in the field, wrapped in "Saran-wrap" and aluminum foil and sub-sampled into 20 cm segments. The cores were returned to the laboratory at the A.I.N.A. Base Camp where the segments were later sub-sampled in 2 cm increments and wrapped in aluminum foil in order to prevent disturbance during shipment. At least three cores were extracted from each of Loon, Fish and Phalarope Lakes. Only one core was extracted from Immerk Lake due to the extreme rockiness of the basin. In addition, two cores were collected from the interior plateau lake (LT1 and LT2) for subsequent pollen analysis.

All 2 cm sub-samples were air-dried (except the samples from Lake Titty which have been retained in a moist condition), weighed and cataloged. The sediments were described using

the terminology of the Canadian Soil Survey (Canada Soil Survey Committee, 1978). Colour was described using a Munsell soil colour chart. Cores will be analyzed by 2, 4, or 6 cm amounts depending on the dry sample weight. The chemical composition of the sediments will be determined using neutron activation analysis, atomic absorption spectroscopy, X-ray fluorescence and a specific ion electrode. Each element to be determined has specific chemical attributes which help to reconstruct the nature of the lake waters, redox conditions and clastic sources of material.

Since the alkali and alkine-earths are relatively insoluble their presence, in abundance, is taken to reflect erosion within the drainage basin (Engstrom and Wright, 1983) and, to some extent, paleosalinity (Ericsson, 1973). The source of these elements is generally land-based clastics. In addition, Ericsson (1973) has suggested that the relative percentage of these elements can indicate former saline conditions. For example, in brackish or salt water the percentage of Na > Mg > Ca > K, however, in fresh water, Ca > Mg > Na > K. Ericsson also noted that the Ca:Na and Mg:Na ratios will increase with decreasing salinity, although the use of Ca and Mg in areas where carbonate rocks are present may hinder interpretation since the input of excess Ca or Mg will keep the ratios at an increased level and therefore changes in the ratio may simply reflect increased or decreased deposition of carbonate materials in the lake. Like the alkali and alkali-earths Al, Si, Ti are also indicative of erosional environments due to their relatively insoluble nature (Burden *et al.*, 1986).

Mackereth (1966) has used Cl and B as indicators of oceanity. He argued that the only way these elements can be input is through the transport of wave spray into the lake basin in the form of rainfall. In addition, Cl and B will increase as soil leaching progresses. This will occur, assuming constant rainfall, because Cl and B, which are derived from rainfall, will be able to occupy more exchange sites in relation to HCO_3^- derived from the soil because the HCO_3^- will be leached out of the system. Subsequently, these elements are washed into the lake. An increase in Cl and B may also result from an increase in rainfall providing excess Cl and B to the lake system (Mackereth, 1966).

Fe and Mn can be used as indicators of soil and vegetation development since they both rapidly form complexes with organic matter (Engstrom and Wright, 1983) which allows the ions to be transported in groundwater to the lake. Once in a lacustrine environment these elements either become mobile under reducing conditions or become converted to hydroxides or chelates under oxidizing conditions. As a result of this behaviour, Mackereth (1966) argued that Fe and Mn could be used to reconstruct paleo-redox conditions. When Fe and Mn are reduced they become mobile and migrate to the sediment/water interface. As the lake water turns over, the free Fe and Mn is flushed out of the lake by way of its drainage system.

Another useful indicator of paleo-redox conditions is the Fe:Mn ratio. Under oxidizing conditions in the soil, or erosional environments the Fe:Mn ratio is close to the lithospheric average. However, when reducing conditions are present in the soil, Mn by virtue of its high solublity, is selectively removed over and above the amount of either mobile or chelated Fe. This results in a decrease in the ratio as Mn builds up in the lake sediments (Engstrom and Wright, 1983).

Since biogenic silica is derived from the frustules of diatoms it provides a useful surrogate for lake productivity. However, it must be fractionated from the clastic silica for analysis. This can be accomplished through a 5% Na_2C0_3 extraction and subsequent colorimetric determination of the biogenic Si concentration of the extract.

Because lake sediments contain elements derived both from clastic (allogenic) and organic lake material (authigenic) these fractions must be separated to obtain a proper interpretation of the geochemical record, otherwise, excess elements contributed by biochemically precipitated carbonates, biogenic silica, metal hydroxides and sulphides may be misinterpreted in the environmental reconstruction. A technique proposed by Engstrom and Wright (1983) will be adapted in this study for use by neutron activation analysis by removing the fractions called for and analyzing the dried extracts, provided enough sample can be obtained.

From each sample 1 g of dry sediment will be set aside for diatom preparation and analysis. The sample will be pretreated with 10% HCl to remove carbonates, then organic matter will be oxidized using 2:1 concentrated H_2S0_4 and M/6 $Kr_2Cr_20_7$ digest. The residue will be washed, suspended in silicon oil and mounted on a glass slide. Frequency will be established using a 500 value count. Once diatoms have been identified they will be grouped into classes. Following Tooley (1978) diatoms will be separated into seven categories based on their salinity tolerances in order to determine the marine/fresh water transition. Fresh water species will be further subdivided into alkaliphilous, indifferent and unknown (Walker, 1978).

Samples from the interior plateau lake cores have been stored frozen until needed for subsampling and pollen extraction to prevent disruption and destruction. 1 g of wet sediment from core LT1 will be prepared for pollen analysis following the method described by Beaudoin (1984) to determine the regional pollen signal which may aid in the interpretation of the geochemical and diatom data. The results will also be compared with the palynological results obtained on a core (TB1) from the Truelove Valley palsa.

The determination of Total Organic Carbon in the sediment samples is necessary in order to determine the amounts of organic matter present. Organic matter is important due to its ability to chelate multivalent ions such as Fe, Mn, and Al and transport them into lacustrine environements via groundwaters (Engstrom and Wright, 1983). It can also be used as a relative measure of lake and soil productivity. Organic carbon will be determined using the modified Walkley-Black (1934) technique.

The chemical data will be presented in chart form, as in Engstrom and Wright (1983) with both authigenic and allogenic fractions displayed along with biogenic Si and Total Organic Carbon. If accurate ^{14}C dates can be obtained on the core, the amounts will be based on accumulation rates. However, realizing the inherent difficulties of obtaining reliable dating control on sediments in an area where free

carbonates are known to exist, the data will likely be represented as units of concentration either in mg/g of dry sediment or percent of mineral/organic matter.

The diatom data will be presented in graph form similar to the pollen data. Since aggregate information is more applicable to this study, the population of individual diatom species will not be graphed, although they will be included in appendices. Instead, the graphs will be subdivided following Tooley (1978) into marine, marine-brackish, brackish-marine, bracking, brackish-fresh, fresh-brackish, fresh water diatoms. Fresh water diatoms will be further subdivided into groups of alkaliphilous, acidophilous, indifferent or unknown, as in Walker (1978). Amounts will be based on a per unit of sediment basis or an exotic marker method as described by Beaudoin (1984). The pollen data will be presented in standard chart form, as in Beaudoin (1984) including species and indeterminant grains. Once again, the amounts will be based on a per unit of sediment basis or the exotic marker method.

Palsa palynology

Since the vegetation of an area responds directly to the controls exerted by environmental factors, it is possible to derive such factors from a reconstruction of the past vegetation (Birks and Birks, 1980). In 1916 von Post introduced quantitative pollen analysis as a method to be used in determining the spatial relationships between pollen in local areas and that of the region as a whole. Since its inception as a tool in paleoenvironmental reconstructions, pollen analysis has become a major component in such work.

Within Truelove Lowland, the progressive accumulation of organic and inorganic sediments within the lakes has led to the formation of ice-cored palsa when the lakes were subsequently uplifted and drained. Given the age of these palsa, the possibility exists that the former lacustrine sediments contain a record of much of the environmental change that has occurred within the coastal lowlands during the Holocene. A major objective of this study is to examine the record of Holocene paleoenvironmental changes preserved in these sediments through an investigation of the pollen spectra (Heyes, 1986).

To this end three palsa were cored in the coastal lowlands during the summer of 1986 using a modified gasoline powered 7.62 cm diameter CRREL ice-coring auger (Rand and Mellor, 1985). Located at elevations of 6.8 m, 29.8 m and 56.5 m.a.s.l. and based on published isostatic rebound curves for the area, the palsa are estimated to have begun forming approximately 4,000, 7,400 and 8,500 years ago respectively. the longest core (TV1), with a length of 2.62 m, was obtained from the highest palsa which has also yielded a basal date of 6,900 ± 115 years B.P. (S-428). Analysis of this core is presently underway. Pollen is being extracted and concentrated from a series of increment samples from the TV1 core prior to identification and counting. Samples have been spiked with *Lycopodium calvatum* in order to determine fossil pollen concentrations (Birks and Birks, 1980). In addition, surface moss palster samples were collected during the summer of 1986 from each of the 14 plant communities identified by Muc and Bliss (1977) in Truelove Lowland. These surface samples were obtained in order to provide a measure of the modern pollen rain and the comparison with the fossil pollen assemblages in the TV1 and LT1 cores.

The pollen and spores will be identified with the aid of a number of keys, including Kapp (1969) and McAndrews *et al.* (1973) together with reference samples belonging to the collection of K.B. Cawker. Wherever possible, the pollen type will be identified to the species level.

Acknowledgments

Field work on Devon Island during 1985 and 1986 and the subsequent laboratory analyses are being supported by an N.S.E.R.C. operating grant to R.H. King. The authors also wish to acknowledge the logistic support provided by the Polar Continental Shelf Project and the use of the facilities at the Arctic Institute of North America's Base Camp at Truelove Lowland. P. Kelly, R.B. Young, K. Law and A. Heyes were also supported by grants from the Northern Scientific Training Program of the Department of Indian and Northern Affairs. Acknowledgement is also made to the field assistance provided by R.M. King during the 1986 field season.

References

Barr, W. 1971. Postglacial isostatic movement in northeastern Devon Island: a reappraisal. Arctic 24:249–268.

Beaudoin, A.B. 1984. Holocene environmental change in the Sunwapta Pass area, Jasper National Park. Unpublished Ph.D. dissertation, University of Western Ontario. 487 p.

Birks, H.J.B. and Birks, H.H. 1980. Quaternary Paleoecology. Edward Arnold, London. 289 p.

Bliss, L.C. 1977. Introduction. In: Bliss, L.C. (ed.). Truelove Lowland, Devon Island, Canada: A High Arctic Ecosystem. University of Alberta Press. 1–11.

Burden, E.T., Naris, G. and McAndrews, J.H. 1986. Geochemical indicators in lake sediment of upland erosion caused by Indian and European farming, Awanda Provincial park, Ontario. Canadian Journal of Earth Sciences 23:55–65.

Canada Soil Survey Committee. 1978. The Canadian System of Soil Classification. Canada Department of Agriculture, Publication 1646. Supply and Services, Ottawa. 164 p.

Davis, M.B. 1968. Pollen grains in lake sediments; redeposition caused by seasonal water circulation. Science 162:796–798.

Engstrom, D.R. and Wright, H.E. 1983. Chemical stratigraphy of lake sediments as a record of environmental change. In: Haworth, E.Y. and Lund, J.W.G. (eds.). Lake Sediments and Environmental History. University of Minnesota Press, Minneapolis. 11–67.

Ericsson, E. 1973. The cation content of Swedish post-glacial sediments as a criterion of paleo-salinity. Geologiska Foreningens i Stockholm Forhandlingar 95:181–220.

Heyes, A. 1986. Paleoenvironmental record preserved in the Truelove Valley palsa, Devon Island, N.W.T. B.Sc. thesis, Department of Geography, University of Western Ontario, London, Ontario (in preparation).

Jenny, H. 1941. Factors of Soil Formation. McGraw-Hill, New York.

Kapp, R.O. 1969. How to Know Pollen and Spores. W.C. Brown, Dubuque, Iowa. 249 p.

Kelly, P. 1986. Numerical analysis of a soil chronosequence, Truelove Lowland, Devon Island, N.W.T. M.Sc. thesis, Department of Geography, University of Western Ontario, London, Ontario (in preparation).

King, R.H. 1969. Periglaciation on Devon Island, N.W.T. Unpublished Ph.D. thesis, University of Saskatchewan, Saskatoon. 470 p.

_____. 1974. Dynamics of Polar Desert-like soils on Devon Island, Canadian Arctic Archipelago. Proceedings, Association of American Geographers 6:18–21.

Law, K. 1986. Postglacial emergence of Truelove Lowland, Devon Island, N.W.T. B.Sc. thesis, Department of Geography, University of Western Ontario, London, Ontario (in preparation).

Mackereth, F.J.H. 1966. Some chemical observations on post-galcial lake sediments. Philosophical Transactions of the Royal Society Series B, 250:165–213.

McAndrews, J.H., Berti, A.A. and Norris, G. 1973. Key to the Quaternary Pollen and Spores of the Great Lakes Region. Life Sciences Miscellaneous Publication, Royal Ontario Museum, Toronto. 61 p.

Mellor, A. 1984. An investigation of pedogenesis on selected Neoglacial moraine ridge sequences, Jostedalsbreen and Jotunheimen, southern Norway. Unpublished Ph.D. thesis, University of Hull. 490 p.

Muc, M. and Bliss, L.C. 1977. Plant communities of Truelove Lowland. In: Bliss, L.C. (ed.). Truelove Lowland, Devon Island, Canada: A High Arctic Ecosystem. University of Alberta Press. 143-154.

Muller, F. and Barr, W. 1966. Postglacial isostatic movement in northeastern Devon Island, Canadian Arctic Archipelago. Arctic 19:263-269.

Rand, J. and Mellor, M. 1985. Ice-coring augers for shallow depth sampling. Report 85-21. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, 22 p.

Rose, J. 1981. Raised shorelines. In: Goudie, A. (ed.). Geomorphological Techniques. George Allen and Unwin, London. 327-341.

Sondheim, M.W. and Standish, J.T. 1983. Numerical analysis of a chronosequence including an assessment of variability. Canadian Journal of Soil Science 63:501-517.

Stevens, P.R. and Walker, T.W. 1970. The chronosequence concept and soil formation. Quarterly Review of Biology 45:333-350.

Tooley, M.J. 1978. Sea-Level Changes: Northwest England During the Flandrian Stage. Clarendon Press, Oxford. 232 p.

Walker, R. 1978. Diatom and pollen studies of a sediment profile from Melynllyn, a mountain tarn in Snowdonia, North Wales. New Phytologist 81:791-804.

Walkley, A. and Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science 37:202-203.

Young, R.B. 1986. The paleolimnology of Truelove Lowland, Devon Island, N.W.T. M.Sc. thesis, Department of Geography, University of Western Ontario, London, Ontario (in prepartion).

ENGINEERED MATERIALS FOR THE CANADIAN ARCTIC OFFSHORE

S.B. Young

Centre for Frontier Engineering Research (C-FER), University of Alberta, Edmonton, Alberta T6G 2E2

Level: Bachelor's

Abstract

Expanding arctic frontier development associated with hydrocarbon exploration in recent years has resulted in new and unique materials engineering challenges. The Canadian arctic offshore poses some of the most severe environmental conditions in the world: a minimum design temperature of −50°C, massive ice loads and ice abrasion, and corrosive oxygen-rich cold seawater. Ice-breaking vessels and artificial islands or caisson exposed to these conditions have been constructed of specially developed steels. However, research and development continues in search of improved materials for greater versatility. Additionally, as arctic offshore experience has increased, it has been necessary to overcome unexpected problems resulting from the use of these new materials in the frontier environment. Materials engineers and metallurgists have concentrated specifically on maintaining steel toughness at low temeratures and overcoming unique corrosion problems resulting from the corrosive seawater combined with severe ice abrasion.

Particular attention has been necessary in the development of welding procedures and welding materials designed to maintain weldment toughness. Also, due to the variable and often susceptible metallurgy of weldments, preferential corrosion evaluation and prevention problems have been, and are being, overcome. The Canadian materials industry has responded, and is continuing, with research and development of materials for the arctic offshore.

Key words: Arctic offshore, metallurgy, steel, corrosion, toughness, welding .

Résumé

Au cours des années récentes, l'exploration pétrolière dans les régions périphériques de l'Arctique a exigé un rapide développement de l'ingénierie boréale et des matériaux de pointe. Les eaux canadiennes de l'océan arctique imposent des conditions ambiantes parmi les plus rigoureuses du monde: les normes de température minimale atteignent −50°C; les charges de glace sont énormes, de même que ses effets d'abrasion, et l'eau froid, fortement oxygénée, est très corrosive. Les brise-glace, les îlots artificiels et les caissons soumis à ces conditions doivent être construits en aciers spéciaux créés à la demande. On poursuit l'effort de R-D pour la mise au point de matériaux de pointe polyvalents. Comme les travaux accomplis dans les eaux arctiques se sont diversifiés, il a fallu résoudre les problèmes inattendus posés par l'emploi de ces nouveaux matériaux dans le milieu glaciel. Les ingénieurs en résistance des matériaux et les métallurgistes ont axé leurs efforts sur le maintien de la résistance des aciers aux températures très basses et sur leur protection contre la corrosion associée à une forte abrasion par les glaces.

Il a fallu accorder une attention particulière à la mise au point des techniques de soudage et des matériaux utilisés afin d'accroître la ténacité des soudures. Le comportement variable de celles-ci et leur fréquente fragilité ont été étudiés: on trouve les parades nécessaires. L'industrie canadienne des matériaux de pointe poursuit son effort de R-D afin de mettre au point les matériaux indispensables à l'exploitation du pétrole sous-marin dans l'Arctique.

Mots-clés: Océan arctique, pétrole sous-marin, métallurgie, aciers spéciaux, corrosion, ténacité, soudage.

Introduction

Expanding engineering frontier development in recent years has resulted in new and unique materials challenges. The Canadian arctic offshore poses some of the most severe environmental conditions in the world. To withstand extremely low temperatures and harsh ice conditions in such remote locations, the materials criteria for arctic offshore structures and vessels are among the most stringent for any region.

The Canadian arctic offshore encompasses the Beaufort Sea/MacKenzie Delta region and northern arctic islands. The

major thrust of engineering development in the past decade has been associated with hydrocarbon exploration: oil and natural gas. Research and development concerned with Canadian arctic marine materials has been minimal, with practical work experience in the arctic offshore environment only recently beginning to establish reliable design precedents. Most materials have been either of foreign development or traditional "southern" materials which have undergone special arctic adaptations.

The standard minimum design temperature in the Arctic is −50°C. The other unique condition is massive ice loads, imposed by features varying from first year sheet ice through to pressure ridges which may be several tens of metres thick. Wave and current considerations are minimal, compared to the East Coast or the North Sea, and materials requirements are correspondingly not strongly influenced by these factors.

Materials design for Arctic marine requirements is significantly different from either East Coast or North Sea design criteria. The minimum design temperature for the Canadian East Coast is only −30°C; sheet ice is minimal, icebergs are occasional, and wave height and forces are a major design influence. Technology for the North Sea has become relatively established; however, it has been based on a minimum design temperature of only −10°C, with negligible ice conditions, but considerable wave and wind loadings.

In addition to the harsh physical conditions of the Arctic marine environments, logistics is another consideration. The challenges of transporting and installing structures are magnified due to remoteness; routine inspection and maintenance of remote fixed structures is often not physically practical.

Papers consulted for this paper are listed at the end.

Steel structures

The majority of Canadian arctic fixed offshore structures are currently fabricated of steel, and are supported by a variety of steel-hulled arctic class vessels, including icebreakers, support ships, and cargo barges. Medium and high strength structural type steels have been the primary materials used in arctic offshore construction, because of the high loads encountered.

Designing structures to withstand ice, wind and wave loads represents a considerable challenge for design engineers because of low service temperatures and limited operating experience in ice-laden ocean waters. For the materials engineer, one major challenge with structural steel is to maintain required strength and rigidity without losing fracture toughness. Complicating this dilemma is corrosion. Already a considerable problem in any marine environment, corrosion in the Beaufort Sea appears to be accelerated by ice abrasion and by the high oxygen content of cold sea water.

The materials science definition for toughness is the measure of energy required for mechanical failure. When overstressed, materials may fail either on a large scale, by macrodeformation of the structure, for example by bending, or on a smaller scale by micro-failure. Two modes of micro-failure are possible: ductile tearing of tough materials, which requires relatively high energy and occurs slowly, or brittle fracture, which requires relatively low energy and occurs suddenly and usually results in failure of a structural member. Designers take care to arrange a structure to fail, if it must, in the former mode. A ductile type failure is preferred because it is relatively slow and therefore usually visible, and thus remedial action can be taken before a catastrophic failure occurs.

One of the ways designers reduce the probability of brittle crack initiation is by minimizing stress concentrations around notches, sharp inside corners, welds or other defects. Eliminating stress concentrations is therefore a design objective, and inspection during construction is aimed at locating and remedying potential defects above a calculated critical flaw size.

Another factor critical to fracture is the rate of loading. Impact on a structure results in a high energy input and therefore creates potential for fracture initiation. The effective ductile to brittle transition temperature is also raised under impact loading. Thus, for structural members prone to impact, such as ice-resisting walls within caissons or ice breaker bows, substantially tougher steels are required than for conventional structures.

At arctic service temperatures, traditional steels change from ductile to brittle behaviour, with substantially reduced fracture resistance. New steels have been developed over the past several years with ductile to brittle transition temperatures around −40°C, and development work is underway on new grades of steel which are tough to −60°C and lower.

Corrosion

Corrosion is an electrochemical process driven by potential differences resulting from dissimilar metallic cells in electrical contact. Sea water, as an excellent conducting solution, acts as the electrolyte in which a combination of two partial reactions occur: the anodic oxidation of the metal, and the cathodic reduction of oxygen in the sea water.

The Beaufort Sea is one of the more corrosive environments of any marine region in the world. Oxygen dissolves very rapidly in cold water, thereby supplying reactants for the corrosion process. Ice abrasion results in removal of protective oxidation products formed on the metal surface, thus exposing it continuously to oxygen. This substantially increases the rate of corrosion attack.

Pitting is the usual corrosion mode on large areas of structural steel plate exposed to the arctic marine environment, as in any sea. Due to oxygen supply and ice abrasion, coupled with the sensitive metallurgy of the arctic steels, average corrosion rates are very severe: 1 mm/year is not uncommon. The greatest difficulties arise when certain regions of metal corrode preferentially. Three distinct areas have been found to corrode preferentially: welds, heat affected zones, and fusion lines. Each situation presents a different problem and therefore requires a different solution. Solving these problems and simultaneously maintaining toughness characteristics is a metallurgical challenge. As an example of the problems preferential corrosion may raise, the heat affected zones of some types of welds have been observed to corrode in a knifeline mode to depths of up to about 2.5 mm/year. These preferential knifelines act as stress raisers for brittle fracture initiation, and are located in an area susceptible to low toughness.

Coatings and cathodic protection systems are conventional solutions to corrosion problems. Coatings inhibit corrosion by insulating the metal from electrolyte and breaking the electrochemical circuit. Maintaining the mechanical integrity of coatings on ice resisting surfaces has, to date, shown mixed results. Some vessels have maintained their coatings very adequately, for example, 90% of the coating intact after two years service, while others have lost almost all their protection in less than a year.

The principle of cathodic protection is to reverse the direction of the reaction current, thus forcing the otherwise anodic steel to become the non-corroding cathode. Conventional cathodic protection systems involving sacrificial anodes as used in the North Sea have not proven effective in the Beaufort. Protruding anodes, however well protected, have been knocked off the hull by ice scour. Further, maintaining proper current distribution throughout the hull is difficult at the higher power levels required in the Beaufort Sea. Recently the use of flush mounted platinized niobium impressed current anodes has proven very effective in cathodic protection systems. Coatings and cathodic protection systems in combination will undoubtedly be developed further.

Welding

Welds in general and welding flaws in particular are often the weakest links in the chain of structural integrity. Regardless of superior base plate properties, if the weld is not sound and it is brittle or highly susceptible to corrosion, structural integrity is reduced. In the arctic offshore, weldments are of particular concern since many of the desirable properties of the plate such as toughness and corrosion resistance, are degraded in the weldment. For instance, high heat affected zone fracture toughness is difficult to obtain. This zone is of base plate chemistry, yet has undergone a metallurgical heat treatment due to the welding process: the cumulative effect on toughness and corrosion is difficult to predict. Design of base plate, welding consumable and welding process, as a cooperative effort, is necessary to minimize the instance of reduced fracture toughness in the heat affected zone and yet not produce preferential corrosion tendencies.

Other structural materials

To date, concrete as a material for the arctic offshore has not required any special adaptations or modifications to meet the challenges of the harsh environment. Current designs for composite steel-concrete ice resisting walls require medium and high strength concrete of conventional materials characteristics. Corrosion of steel reinforcement within the concrete is possible, but initial indications are that this problem may be solved by conventional technologies such as epoxy precoating of the bars or by cathodic protection of the structural reinforcement.

A unique and readily available material for arctic offshore structures is ice itself. Natural rubble fields around caissons and artificial islands act as a buffer zone protecting the structures from ice forces. In a few trial locations, water has been pumped and sprayed to form an artificial ice field around the structure.

In the arctic islands, conventional land drilling rigs have been successfully used directly atop the ice sheet itself, with the ice artificially thickened to a minimum depth of six metres by pumping sea water on top of the sheet in early winter.

Materials research

Canadian participation in arctic materials research and development has begun. The versatility of steel as a suitable construction material is being tested to meet the very stringent requirements of the arctic offshore. Stelco has developed a controlled rolled grade 350 WT plate specially for arctic applications taking steel weldability into consideration. Algoma has produced and tested a steel for offshore and arctic use, certifiable to Lloyd's LT60 specification. For the future, corrosion considerations and weldability in conjunction with welding procedure development for toughness maintenance will be major considerations in the design of arctic grade steels. Significant foreign development has already been accomplished in this direction, specifically in Japan and Scandinavia.

With regard to the Canadian support technologies for arctic steels, like corrosion resistance systems and welding developments, research and development will continue to contribute. For example, C-FER has devised a repair weld technique suitable for $-30°C$ ambient temperatures and is continuing research on cold welding technology and weldment corrosion.

Today, steel is the major arctic structural material and, for the future, it will remain the basis for vessels and exploration structures where optimum short term performance and versatility are necessary, and maintenance is physically possible. With increased petroleum and natural gas exploration and expected development, growing numbers of icebreakers and support vessels will be required. In addition to these vessels, other requirements for steel vessels will emerge such as bulk carriers and naval vessels.

For the long term, fixed arctic offshore structures necessary for hydrocarbon production platforms will be required to survive for periods of thirty years in the harsh arctic marine environment. Steels will remain of primary interest but concrete may be a particularly attractive additional construction material. Ice too should also be considered as a material available for special designs.

Summary

The new frontier of the Canadian arctic offshore poses unique materials requirements. With experience, problems are being identified and appropriate research and development have been initiated to address these challenges. The Canadian materials industry has shown its ability to respond although continuing research and development will be necessary.

Note

A previous version of this paper was published:

Young, S.B., 1986. Materials in the Canadian Arctic Offshore. Marine Engineering Digest, Vol. 5, No. 4, Spring 1986, 30-32.

References

Ackert, R.J. et al. 1984. "LT60 Plate for Arctic Application". The Algoma Steel Corporation, Ltd., Canadian Institute of Mining and Metallurgy 23rd Annual Conference, Quebec, Quebec (August 1984).

CANMET, 1983. Proceedings of the Study Session on Fracture Toughness Evaluation of Steels for Arctic Marine Use. Ed. R. Thomson, C.S. Champion.

Croasdale, K.R., 1984. "Sea Ice Mechanics: A General Overview". Marine Technology Society Journal, Marine Technology Society, Washington, D.C., Vol. 18, No. 1, pp. 8-16.

Dawson, G.W. and Judson, P., 1982. "Procedural Guidelines for the Achievement of Tough Welded Joints in Structural Steels for Offshore Applications". 2nd International Conference on Offshore Welded Structures, London (November, 1982).

Gilmour, J.B. 1980. "The Corrosion of Welds in Ice-Breaking Ships — A Review". CANMET Report 80-14E.

Havasawa, H. et al., 1985. "The Development of Welding Procedures for Arctic Structures and Offshore Platforms Using TMCP Steel Plates". Nippon-Kokan. International Conference on "Welding for Challenging Environments". Welding Institute of Canada (October 1985).

Luft, H.B. et al., 1986. "Repair Welding of Arctic Offshore Structure and Vessels". Proceedings of the 4th International Conference on Cold Regions Engineering, Anchorage, Alaska (Februry 1986).

McCutcheon, D.B., 1984. "Controlled Rolled Grade 350 Plate for Arctic Applications". Stelco Inc., Canadian Institute of Mining and Metallurgy 23rd Annual Conference, Quebec (August 1984).

Van Hee, G. et al., 1984. "Engineering Systems for Offshore and Arctic Hydrocarbon Development". Canadian Institute of Mining and Metallurgy 23rd Annual Conference of Metallurgists, Quebec, Quebec (August 1984).

CANADIAN PERMAFROST DISTRIBUTION AND THICKNESS DATA COLLECTION: A DISCUSSION

S. Young[1] and A.S. Judge[2]

1 Faculty of Environmental Studies, Department of Geography, University of Waterloo, Waterloo, Ontario N2L 3G1
2 Terrain Sciences Division, Energy, Mines and Resources, Ottawa, Ontario K1A 0E4

Level: S. Young, Bachelor's

Abstract

Permafrost underlies over 50% of the Canadian land area. With current interest and development in the Canadian north, the importance of cataloguing the distribution and thickness of permafrost arises. Consequently, a *Canadian Permafrost Distribution and Thickness Data Collection* has been developed. The collection, for 1067 locations, combines thickness information in the literature with precise temperature observations from downhole measurements and interpretations of the base of ice-bearing permafrost from geophysical well logs.

Preliminary analysis indicates permafrost thicknesses as deep as 900 metres in some locations. Average Canadian thickness of 258 metres may be compared with regional averages of 368 metres for East of Hudson Bay, 281 metres for West of Hudson Bay, and 221 metres for the Western Arctic. Although, in general, permafrost thickness increases from south to north the correlation coefficient of thickness with latitude is only 0.64.

The database of almost 1000 determinations was compiled using Lotus 1-2-3 and is available from Terrain Sciences, Geological Survey of Canada on diskettes for use on an IBM-PC.

Key words: Canada, permafrost, collection, database, ground temperature.

Résumé

Cinquante pour cent de la superficie du Canada est couverte par le pergélisol. L'intérêt actuel accordé au Nord canadien et à son développement met en relief l'importance d'un relevé de la répartition et de l'épaisseur de ce pergélisol. En conséquence, l'auteur a compilé un *Répertoire de données sur la répartition et l'épaisseur du pergélisol au Canada*. Les données, qui concernent 1 067 emplacements, portent sur l'épaisseur rapportée dans la littérature technique, les températures mesurées avec précision dans les trous de sondage, et la limite inférieure supposée du pergélisol, d'après les diagraphies de forages géophysiques.

L'analyse préliminaire des données montre qu'en certains emplacements le pergélisol atteint jusqu'à 900 m d'épaisseur. L'épaisseur moyenne du pergélisol du Canada est de 258 m, de 368 m à l'Est de la baie d'Hudson, de 281 m à l'Ouest de cette baie, et de 221 m dans l'Arctique occidental. Bien qu'en général l'épaisseur du pergélisol croisse en allant du Sud vers le Nord, le coefficient de corrélation de cette épaisseur avec la latitude n'est que de 0,64.

L'auteur a compilé les bases de données relatives à 1 000 emplacements grâce au Lotus 1-2-3. Les données sont disponibles auprès de la Division de la science des terrains, Commission géologique du Canada, sur disquettes lisibles par un IBM-PC.

Mots-clés: Pergélisol du Canada, recueil des données, températures, géophysique, analyse.

Permafrost is a pervasive condition in northern Canada that affects many aspects of life and nature. An understanding of permafrost is of vital importance in almost all phases of programs for development in northern regions (Heginbottom *et al.*, 1978). Knowledge of permafrost thickness is desirable for a variety of engineering and scientific reasons. Special drilling, well completion, and production procedures are required for wells drilled in permafrost. Assessment of the potential distribution of gas hydrates in or under permafrost, the construction of regional groundwater models, and assessment of geothermal resources require detailed information on permafrost thickness and distribution (Osterkamp and Payne, 1981).

Permafrost is a thermal condition of earth materials when their temperature remains below 0°C for two or more years.

The term includes ground that freezes one winter and remains frozen throughout the following summer and into the next winter; this is the minimum duration of permafrost (Brown and Péwé, 1973; Brown, 1974). However, soil or rock technically described as being permafrost (0°C), may contain various amounts of water and ice in a combination of frozen, partially frozen, or completely frozen materials. The permafrost soil may contain pure ice, ice lenses, ice in pores and fractures, or may occur as a bedrock material containing no ice or moisture at all (Judge, 1975).

The possible existence of permafrost at a location represents a complex balance of energy sources, originating from the interior and exerior of the earth. Jessop (1972) and Judge (1973a, 1974a) describe the nature of the earth's energy balance and how it corresponds to the distribution of permafrost. The basic important factors include the present and past mean annual surface temperatures, the terrestrial heat flux, the thermal properties of the earth materials and the state of the moisture present in these materials (Judge, 1975).

Until recently, detailed information on permafrost thickness in Canada was sparse and randomly scattered. Increased drilling activity, particularly in oil and gas exploration has greatly increased the available information. Many estimates of deep permafrost thickness using geophysical well logs have been made, however, much of this material is not in the public domain. Further, permafrost thickness based on temperatures measured in boreholes in, or almost in, thermal equilibrium are even less common (Judge, 1973b).

Consequently, in an attempt to compile permafrost information in a useful format for further research, a *Canadian Permafrost Distribution and Thickness Data Collection* has been developed. The collection, for 1067 locations, combines thickness information in the literature with precise temperature observations from downhole measurements and interpretations of the base of ice bearing permafrost from geophysical well logs.

The purpose of this paper is to briefly explain the rationale for the *Canadian Permafrost Distribution and Thickness Data Collection*. Additionally, some regional analysis is discussed. The *Collection* itself includes: a review of the ground thermal regime, a discussion of surface temperature variation, an historical perspective on permafrost research, the rationale for the database parameters and construction, and additional source and site specific information.

One of the earliest observations of permafrost thickness made in North America was made by McPherson at Fort Simpson (Richardson, 1841) in 1836. More modern studies were made at Resolute (Misener, 1955) and at Winter Harbour (Jacobsen, 1963) with thermister cables in deep hole installations. For the decade following these measurements,

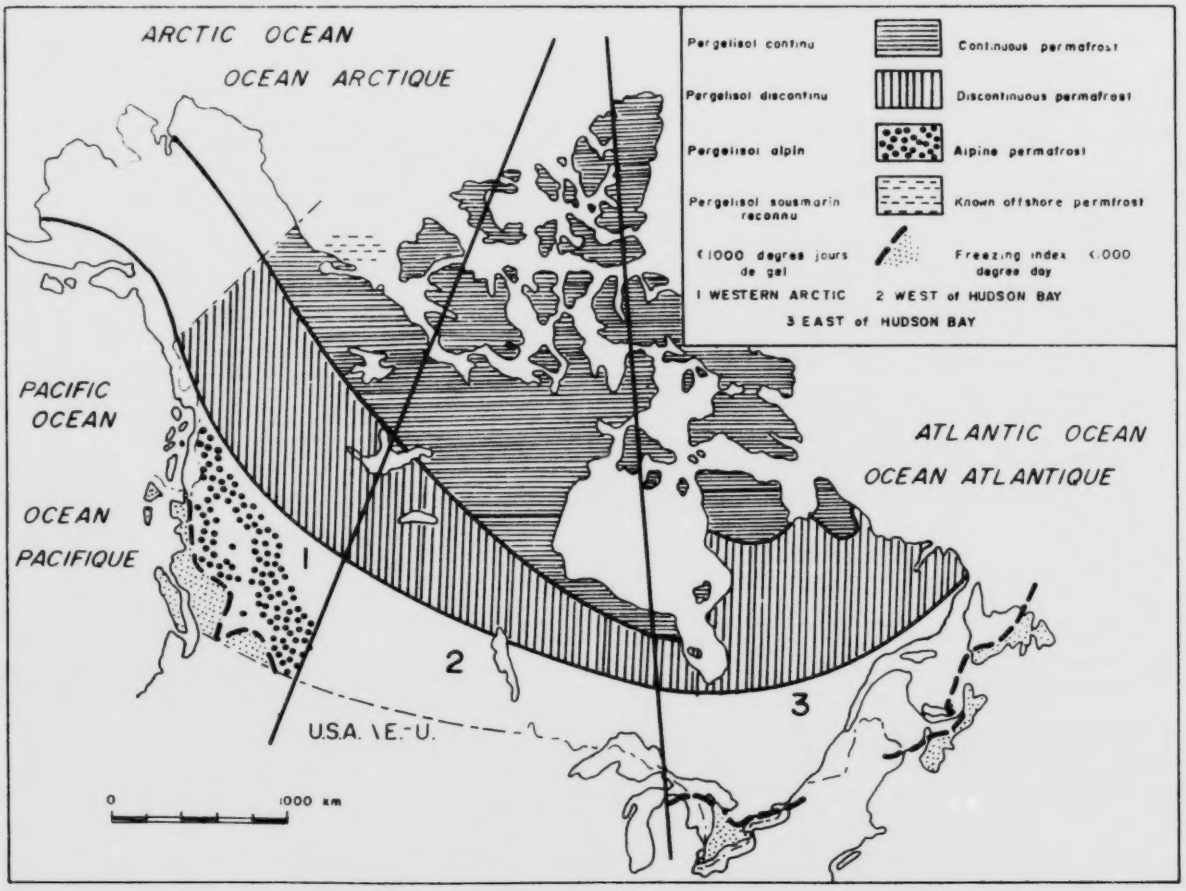


Figure 1. Permafrost Distribution in Canada. Permafrost map after Brown, R.J.E., Hydrological Atlas of Canada, 1978.

little other ground temperature data was available (Taylor *et al.*, 1983). This is primarily because of the difficulties encountered and the high expense involved in drilling through permafrost (Judge, 1974a).

With assistance from industry in the preservation of boreholes, approval from government regulators and logistical support from the Polar Continental Shelf Project, the Terrain Sciences Division of the Geological Survey of Canada (formerly the Earth Physics Branch) has made temperature measurements to depths of 125 m or more at 129 sites in northern Canada (Judge, 1973b; Taylor *et al.*, 1982 and preceding Geothermal Series publications).

More recently, geophysical consulting companies were contracted to study well logs to outline permafrost thickness and/or gas hydrate occurrence (D&S Group, 1983; Hardy Associates Ltd., 1984a, b). Summary results from these reports were presented at a permafrost geophysical workshop (Brown *et al.*, 1985) held in Colorado in 1984 (Judge and Taylor, 1985).

Thus, the object of the *Collection* is to make available all information on permafrost currently available in Canada in one computer accessible database.

Permafrost in general

Approximately 22 to 25% of the earth's land surface is underlain by permafrost (French, 1976). In Canada and the Soviet Union over 50% of their respective land areas are affected (Brown, 1970). Permafrost is also found in northern Scandinavia, China, parts of central Asia, Spitsbergen, Iceland, Antarctica, and at high elevations in many mountainous regions of the world (French, 1976).

Permafrost is divided regionally into continuous, discontinuous and sporadic zones of occurrence. Figure 1 illustrates these divisions. The southern limits of the discontinous and continuous zones of permafrost in North America correspond approximately with the $-1°C$ to $-6°C$ mean annual air temperature isotherms, respectively (Brown, 1978).

Climate is the main factor influencing the formation and existence of permafrost. The temperature at the earth's surface is the upper limiting condition for underground temperatures. The surface temperature, which varies both spatially across the earth's surface and temporally from day to day, is largely governed by energy sources external to the solid earth, specifically air temperatures and general weather conditions (Judge, 1973a; Andersland and Anderson, 1978). The shallow ground temperature data collection for northern Canada (Young, 1985) contains all publicly available ground temperature information.

The base of permafrost corresponds with the equilibrium depth at which the temperature increase due to the earth's internal heat offsets the amount of heat loss at the earth's surface (Lachenbruch *et al.*, 1962). The depth of permafrost is thus determined largely by a mean surface temperature which is a summation of values created through processes acting over long periods of time. Annual seasonal fluctuations of temperature about the mean control the upper permafrost boundary. Figure 2 is a diagrammatic sketch of the thermal regime in permafrost. Permafrost thickness is equivalent to the distance between the upper permafrost table and 0°C isotherm.

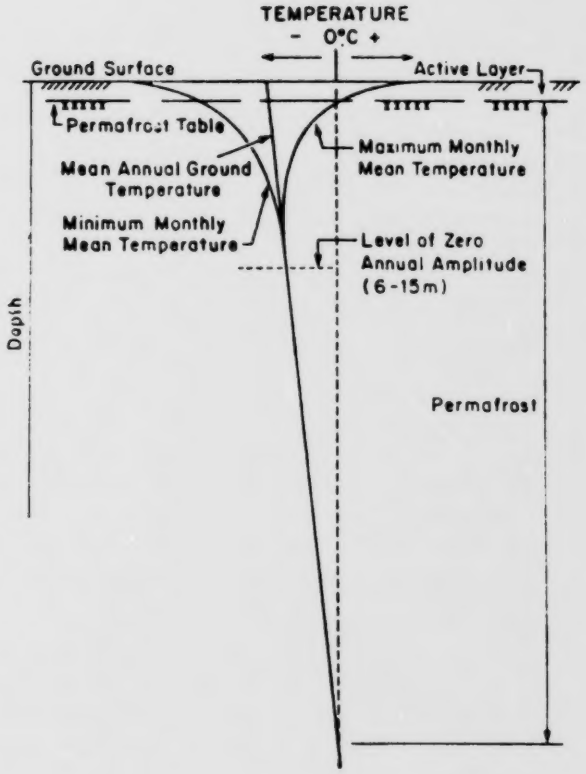


Figure 2. Diagrammatic sketch of the thermal regime in permafrost.

Local variations of ground temperature (and permafrost conditions) are due to a variety of factors such as snow cover (Krinsley, 1963; Annersten, 1964; Nicholson, 1978; Morrisey, 1983), topography (Harlan and Nixon, 1978; Brown, 1966; Morrisey, 1983), wind characteristics (Annersten, 1964; Ives, 1961; Granberg, 1973) ground and vegetation cover (Brown, 1968; Brown and Johnston, 1964; Crampton and Rutter, 1973), and surface moisture (Gold and Lachenbruch, 1973; Haugen *et al.*, 1983). The most important factors in the difference between air and ground temperatures are the thickness and time of persistence of snow cover in winter (William and Gold, 1976; Gold and Lachenbruch, 1973).

Judge (1973c) reports the mean northward displacement of the ground surface isotherm relative to the equivalent air temperature in northern Canada as 3.3C° with a standard deviation of 1.5C° based on 38 data points. In a recent study, based on 386 data points, Young (1985) reports the average mean air and ground temperature differences as 4C° with a standard deviation of 2C°.

Terrain damage due to degradation of permafrost is significant in soils with a high ice content and a surface cover whose characteristics are sensitive to physical disturbance. Serious damage occurs primarily in terrain with peat cover underlain by ice rich fine grained soils (Gold and Lachenbruch, 1973). The removal of tree cover (i.e. on road, utility or pipeline tracts) generally results in a modified

surface temperature which subsequently causes a deepening of the active layer after clearing. The magnitude of the disturbance on thaw depth will depend on the degree and nature of the disturbance, the thermal properties of the soil, their ice content and on prevailing climatic conditions.

When the mean annual ground-surface temperature exceeds 0°C, melting of the permafrost table proceeds very slowly. A scale of about a century is required to melt 10 to 20 m (Osterkamp, 1983). Judge (1974a) reports that a surface increase by 2K° may cause permafrost to degrade by as much as 90 m in a period of 100 years and may completely disappear in the marginal areas. Thie (1974) estimated that rates of permafrost degradation in northern Manitoba varied between 5 and 20 m over the 20 year period 1947–1967. In more northerly latitudes, permafrost degradation occurs at a slower rate (Harlan and Nixon, 1978).

Papers by Bliss and Wein (1971, 1972), Mackay (1966, 1970) and Watmore (1969) explore the problems of active layer thickening and related thaw settlement and erosion (thermokarst). Bliss and Wein (1971), Brown *et al.* (1969), Heginbottom (1971, 1973), and Vierich (1973), among others, investigated the influence of fire on permafrost. Papers by Smith and Riseborough (1983), Smith (1984), Mackay (1975) and Washburn (1980), among others, discuss the possible effects of climatic change on the distribution and thickness of permafrost. Other natural processes that affect the ground thermal regime are sedimentation, solifluction, and of course, vegetative change.

The database

Using Lotus 1-2-3, a spreadsheet software program, on an IBM-PC, data was recorded under the following headings: Location, Site, Latitude (°N), Longitude (°W), Elevation (msl), Determination, Permafrost (base of IBPF, transition, to 0°C isotherm), Mean Annual Ground Temperature (°C), Mean Annual Air Temperature (°C), Temperature Gradient (C° km^{-1}), Slope, Average Annual Snowfall (cm), Vegetation Cover, Moisture Content (% by volume), Active Layer Depth (cm), Lithology, Earth Materials, Permafrost Zone, Nearest Water Body (km), Other Features (comments), Period and References. Specific explanations for each column are outlined in the *Collection*. The following paragraphs discuss some of the more important headings and their meanings.

Permafrost (Base of ice bearing permafrost, base of transition to 0°C isotherm)

Permafrost, defined as a thermal condition of the ground, is not required to be in a frozen state. Thus, materials containing ice in the pore spaces and those without are both considered permafrost. The application of petrophysical logging techniques are dependent on the recognition of physical changes in the log response to the presence of ice (Hardy Associates Ltd., 1984a). Following Osterkamp and Payne (1981), frozen ground is denoted as ice-bearing permafrost (IBPF) and unfrozen ground below 0°C as permafrost *per se*.

The base of permafrost corresponds to the position of the 0°C ground temperature isotherm, therefore, permafrost thickness can only be delineated on the basis of precise temperature surveys. The base of IBPF may be determined, as shown in Hardy Associates Ltd. (1984a,b) and D&S Group (1983), based on interpretation of petrophysical data (downhole well logs).

The bases of the 0° isotherm and IBPF rarely correspond except in coarse-grained materials with fresh water in the pores. A difference in temperature generally occurs marking the two depths (Hardy Associates Ltd., 1984a). A function of pressure, chemical and soil particle effects, this difference is termed the freezing point depresion (FPD) by Osterkamp and Payne (1981). IBPF will strictly coincide with permafrost only for pure water, in a large container, under the pressure of one atmosphere (D&S Group, 1983).

Most well logs also exhibit a transition zone below the IBPF base, where the resistivity and sonic travel times gradually change. The results of Hardy Associates Ltd. (1984a,b) indicate that the thickness of the transition zone may range from about 10 m to greater than 100 m. This is likely a function of lithology and temperature and is analogous to the relationship between discontinuous and continuous permafrost. Water and ice will co-exist in fine pore spaces, so that the transition zone may represent the increasing unfrozen moisture content as the temperature rises with depth (Desai and Moore, 1968). Similarly, the transition zone between no permafrost occurrences to continuous permafrost may extend varying distances, across Canada.

Determination indicates the method used to determine that recorded permafrost thickness (i.e. temperature measurements, geophysical well log interpretation etc.).

Combining data from different studies using different methods and with different purposes has inherent problems with the continuity of accuracy and the confidence limits. The *Collection* itself outlines the strengths and uncertainties of each of the reference sources utilized.

Discussion

In total, 1067 locations citing permafrost occurrences are recorded in the *Collection*. Of those thicknesses, there are 546 measurements of the direct base of IBPF, 341 sites additionally record a transition zone and 433 sites provide a direct measure of the depth to the 0° isotherm.

The mean thickness of permafrost in Canada is 258 metres (978 values). The most southerly reported occurrence of permafrost in eastern Canada is at *Mont Jacques Cartier* (48°56′N 65°55′W), and in western Canada, at *Plateau Mountain* (50°12′N 114°32′W). Both of these occurrences are at high elevations. The most southerly occurrences at modest elevation (i.e. 0–100 msl) occur in northern Ontario around 51°N latitude.

The most northerly reported value is at *Alert, N.W.T.* (82°30′N 62°26′W) with an extrapolated thickness of about 600 m. *Neil 0–15* (80°45′N 83°05′W) is the most accurately measured high latitude site with a reported thickness of 549 m.

The greatest reliable thickness recorded to the base of the IBPF occurs at the offshore borehole *Issungnak 0–61* (< 900 m) using geophysical methods of delineation. The greatest thickness reported by extrapolating temperature

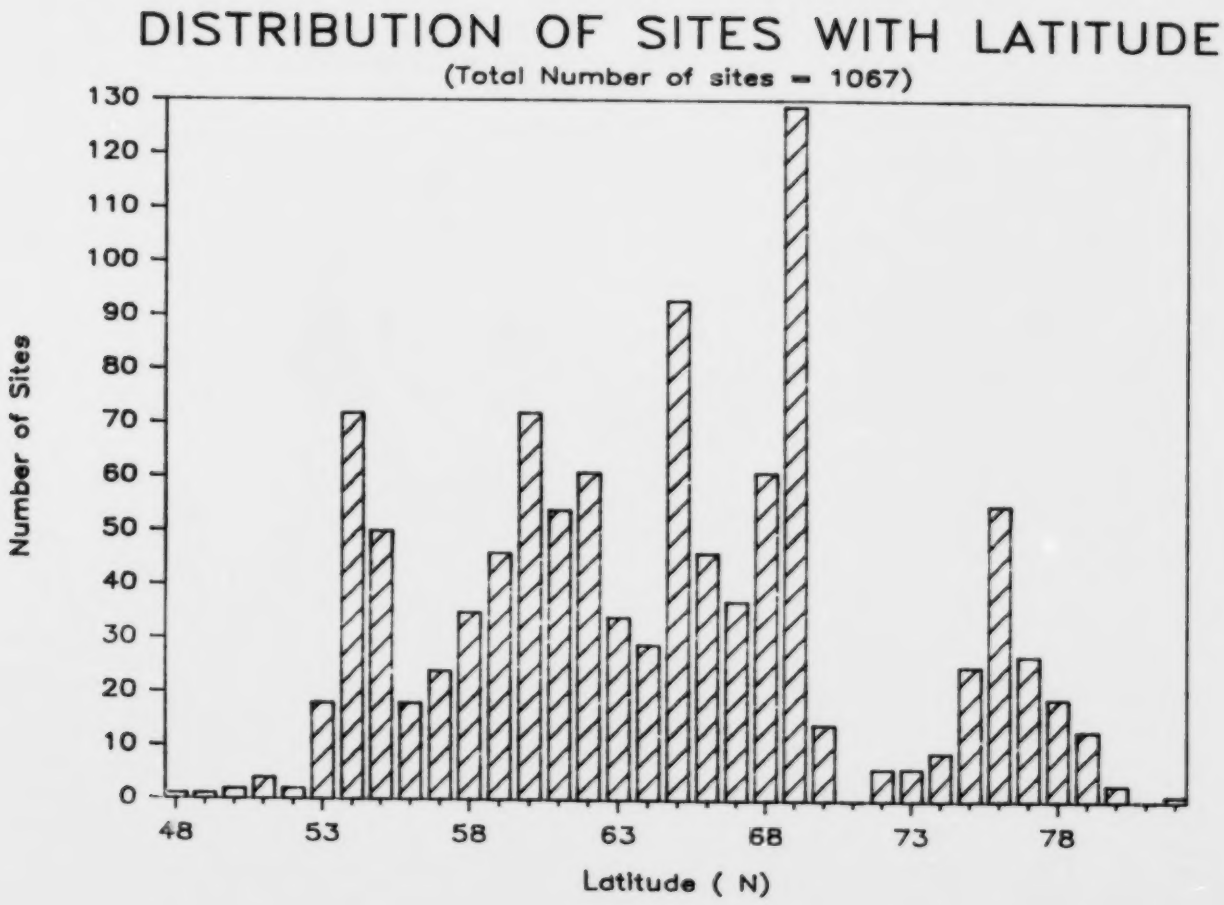


Figure 3. Distribution of sites per degree of latitude.

measurements is 665 m at *Ya Ya A-28* in the Mackenzie Delta. The two regions of generally greatest permafrost thickness are south-central Arctic Islands (especially Cornwallis Island) and the offshore area beneath the Beaufort Sea Shelf.

Three broad sub-regions of Canada: East of Hudson Bay (85°W longitude or less), West of Hudson Bay (85–115°W longitude), and Western Arctic (115°W longitude and greater) are the divisions used for preliminary regional analysis. Figure 1 illustrates these regional divisions. Regional permafrost thickness averages are 368 m (40 values) for east of Hudson Bay, 281 m (268 values) for west of Hudson Bay, and 221 m (678 values) for the western Arctic.

Figure 3 shows the distribution of sites per degree of latitude. A relatively complete coverage is shown, although, there is a strong predominance of sites located between 60 and 70°N. These are sites located in the Mackenzie Valley/Delta region.

Correlation of permafrost distribution with latitude

Young (1985) and Young and Judge (1985) found a high degree of negative correlation between ground and air temperatures versus latitude. The correlation coefficient (r) for MAGT and MAAT with latitude is 0.89 (386 values) and 0.91 (175 values), respectively. Both have negative gradient values dropping approximately 0.7°K per degree of latitude. Air temperatures appear to have a slightly higher correlation and to be less variable than ground temperatures probably because regional air temperatures are affected by fewer lower variables than ground temperatures (Young and Judge, 1985).

Although permafrost thickness is dependent on ground temperatures it is also dependent on the regional terrestrial heat flow through the earth's crust, on the thermal properties of the earth material and on the thermal history of the surface over tens of thousands of years. Thus, there seems to be little direct correlation between latitude and the thickness of permafrost. The correlation coefficients for (1) the base of IBPF and (2) depth to the 0° isotherm versus latitude are +0.32 (546 values) and +0.69 (433 values), respectively. The combined IBPF and 0° isotherm values versus latitude have a correlation coefficient of +0.64.

These lower correlations can partly be explained by considering the interactive role played by surface temperature, surface temperature history, terrestrial heat flow and thermal properties of the ground on the base of permafrost. Terrestrial heat flow is a tectonic factor rather than a latitudinal

factor. This is illustrated by the geological youth of tectonic events occurring in the Sverdrup Basin in the Canadian high arctic compared with the Precambrian Shield area of northern Ontario further to the south. In fact, the measured heat flow in the Sverdrup Basin is 72 mWm^{-2} whereas typical values for the Shield are 40 mWm^{-2} (Jessop *et al.*, 1984).

Also, thermal properties of the ground are dependent on the lithology which is a function of geology, again, not a latitudinally dependent factor. A combination of high terrestrial heat flux and low thermal conductivity (shale lithology for example) will result in thin permafrost even in the presence of low surface temperature. The reverse is also true for low heat flow and high thermal conductivity at higher surface temperatures.

In summary, the *Canadian Permafrost Distribution and Thickness Data Collection* makes available information on permafrost in Canada as delineated directly by temperature measurement, by visual observation and/or by the interpretation of geophysical well logs. Previous studies have developed regional data bases and/or developed specific methods of detecting permafrost. This collection combines all previously reported permafrost thicknesses. Further analysis of statistical correlations between the various parameters affecting permafrost occurrence and thickness is highly recommended. This data collection provides an important tool for the analysis of the parameters controlling permafrost thickness and distribution.

Acknowledgments

The preparation of the database was completed while the author was a co-op student from the University of Waterloo working at the Earth Physics Branch of Energy, Mines and Resources. I would like to thank Dr. Alan Judge, Dr. Wayne Pollard, Dr. Geoff McBoyle, Dr. A. (Sandy) McLellen, Margo Burgess, Darrell Jones, Andrew Paterson and Peter McCarthy for their constant help and encouragement.

References

Andersland, O.B., and Anderson, D.M. 1978. Geotechnical engineering for cold regions. McGraw-Hill Book Company. New York.

Annersten, L.J., 1964. Investigations of permafrost in the vicinity of Knob Lake, 1961–62. J.B. Bird, ed. McGill Subarctic Research Papers no. 16:51–137.

Bliss, L.C., and Wein, R.W. 1971. Changes in the active layer caused by surface disturbance. 37–46 in: Proceedings, Conference on Permafrost Active Layer. National Research Council of Canada, Technical Memorandum 103. Ottawa.

Bliss, L.C., and Wein, R.W. 1972. Plant community responses to disturbances in the western Arctic. Canadian Journal of Botany 50:1097–1109.

Brown, J., Rickard, W., and Vietor, D. 1969. The effect of disturbance on permafrost terrain, US Army Cold Regions Research Engineering Laboratory, Special Report 138. 13 p.

Brown, J., Metz, M.C., and Hoekstra, P., eds., 1985. Workshop on permafrost geophysics. (Golden, Colorado, 23–24 October, 1984) US Army Cold Regions Research Engineering Laboratory, Special Report 85–5.

Brown, R.J.E., 1966. Influence of vegetation on permafrost. 20–25 in: Permafrost International Conference (Lafayette, Ind., 11–15 November, 1963) Proc: National Academy of Science — National Research Council Publication 1287. 563 p.

Brown, R.J.E., 1970. Permafrost in Canada — Its influence on northern development. University of Toronto Press. 234 p.

Brown, R.J.E., 1974. Distribution and environmental relationships of permafrost. Proceedings of Permafrost Hydrology Workshop Seminar 1974:1–5.

Brown, R.J.E., 1978. Influence of climate and terrain on ground temperatures in the continuous permafrost zone of northern Manitoba and Keewatin District, Canada. 15–21 in: Third International Conference on Permafrost (Edmonton, Alberta, 10–13 July, 1978) Proc 1: National Research Council of Canada, Ottawa. 947 p.

Brown, R.J.E., and Johnston, G.H. 1964. Permafrost and related engineering problems. Endeavour XXIII (89):66–72.

Brown, R.J.E., and Péwé, T.L. 1973. Distribution of permafrost in North America and its relationship to the environment: A review, 1963–1973. 71–100 in: North American Contribution, Permafrost Second International Conference (Yakutsk, USSR, 13–28 July, 1973) Washington D.C., National Academy of Science. 783 p.

Crampton, C.B., and Rutter, N.W. 1973. A geoecological terrain analysis of discontinuous frozen ground in the upper Mackenzie Valley, Canada. 101–104 in: North American Contribution, Second International Conference (Yakutsk, USSR, 13–28 July, 1973) Washington D.C., National Academy of Science. 783 p.

D&S Group, 1983. Study of well logs in the Mackenzie Delta — Beaufort Sea to outline permafrost thickness and/or gas hydrate occurrence. Earth Physics Branch Open-File Report 83–10. E.M.R., Ottawa. 242 p.

Desai, K.P., and Moore, E.J. 1968. Well log interpretation in permafrost. The Log Analyst. January-February:13–25.

French, H.M., 1976. The periglacial environment. Longman Group Ltd., London. 309 p.

Gold, L.W., and Lachenbruch, A.H. 1973. Thermal conditions in permafrost — A review of North American literature. 2–23 in: North American Contribution, Permafrost Second International Conference (Yakutsk, USSR, 13–28 July, 1973) Washington D.C., National Academy of Science. 783 p.

Granberg, H.B., 1973. Indirect mapping of the snow cover for permafrost predictions at Schefferville, Quebec. 113–120 in: North American Contribution, Permafrost Second International Conference (Yakutsk, USSR, 13–28 July, 1973) Washington D.C., National Academy of Science. 783 p.

Hardy Associates Ltd., 1984a. Study of well logs in the Arctic Islands to outline permafrost thickness and/or gas hydrate occurrence. Earth Physics Branch Open-File Report 84–8. Energy, Mines and Resources. Ottawa. 374 p.

Hardy Associates Ltd., 1984b. Study of well logs in the western N.W.T. and Yukon to outline permafrost thickness and/or gas hydrate occurrence. Earth Physics Branch Open-File Report 84–27. Energy, Mines and Resources. Ottawa. 290 p.

Harlan, R.L., and Nixon, J.F. 1978. Ground thermal regime: geotechnical engineering for cold regions. 103–150 in: Orlando B. Andersland and Duwayne M. Anderson., ed., McGraw-Hill Book Company, U.S.A.

Haugen, R.K., Outcalt, S.I., and Harle, J.C. 1983. Relationship between estimated mean annual air and permafrost temperatures in north central Alaska. 463–467 in: Permafrost: Fourth International Conference, Proceedings (Fairbanks, Alaska, 17–22 July, 1983) Washington, D.C., National Academy Press. 1524 p.

Heginbottom, J.A., 1971. Some effects of a forest fire on the permafrost active layer at Inuvik, N.W.T. National Research Council Associate Committee on Geotechnical Research. Technical Memorandum 103:31–36.

Heginbottom, J.A., 1973. Some effects of surface disturbance on the permafrost active layer at Inuvik, N.W.T., Canada. 649–657 in: North American Contribution, Permafrost Second International Conference (Yakutsk, USSR, 13–28 July, 1973) Washington D.C., National Academy of Science. 783 p.

Heginbottom, R.K., Kurfurst, P.J., and Lau, J.S.O. 1978. Regional occurrence of permafrost, Mackenzie Valley, Canada. 399–405 in: Third International Conference on Permafrost (Edmonton, Alberta, 10–13 July, 1978) Proc 1: National Research Council of Canada, Ottawa. 947 p.

Ives, J.D., 1961. A project for permafrost investigations in central Labrador-Ungava. Geographical Paper 28, Department of Mines and Technical Surveys, Geographical Branch. Ottawa.

Jacobsen, G., 1963. Deep permafrost measurement in North America. Polar Record 11(74):595–596.

Jessop, A.M., 1972. Heat flow and permafrost. Canadian Institute of Mining Metallurgy Bulletin. November:45–48.

Jessop, A.M., Lewis, T.J., Judge, A.S., Taylor, A.E., and Drury, M.J. 1984. Terrestrial heat flow in Canada. 239–261 in: V. Cermak, L. Rybach and D.S. Chapman ed., Terrestrial Heat Flow Studies and the Structure of the Lithosphere. Tectonophysics 103.

Judge, A.S., 1973a. The thermal regime of the Mackenzie Valley: Observations of the natural state. Environmental Social Committee Northern Pipelines (Canada), Task Force on Northern Oil Development Report 73-38. 177 p.

Judge, A.S., 1973b. Deep temperature observations in the Canadian north. 35-40 in: North American Contribution, Permafrost Second International Conference (Yakutsk, USSR, 13-18 July, 1973) Washington D.C., National Academy of Science. 783 p.

Judge, A.S., 1973c. The prediction of permafrost thickness. Canadian Geotechnical Journal 10:1-11.

Judge, A.S., 1974a. Geothermal measurements in northern Canada. 301-311 in: Proceedings Symposium on Geology of Arctic Canada. G.A.C. — C.S.P.G. Saskatoon.

Judge, A.S., 1974b. The occurrence of offshore permafrost in northern Canada. 427-437 in: Beaufort Sea Symposium, Arctic Institute of North America, San Francisco.

Judge, A.S., 1975. Geothermal studies in the Mackenzie Valley by the Earth Physics Branch. Geothermal Series no. 2, Geothermal Service of Canada, Earth Physics Branch, Energy, Mines and Resources. Ottawa.

Judge, A.S., and Taylor, A.E. 1985. Permafrost distribution in northern Canada: Interpretation of well logs. US Army Cold Regions Research Engineering Laboratory, Special Report 85-5.

Krinsley, D.B., 1963. Influence of snowcover on frost penetration. U.S. Geological Survey Professional Paper 475-B Art. 38. B-144-147.

Lachenbruch, A.H., Brewer, M.C., Greene, C.W., and Marshall, B.V. 1962. Temperature in permafrost. 791-803 in: Temperature — Its Measurement and Control in Science and Industry 3, Part 1, New York, Reinhold Publishing Corp.

Mackay, J.R., 1966. Tundra and taiga. Future environments of North America. F. Darling and J.P. Milton ed. Natural History Press, New York: 151-171.

Mackay, J.R., 1970. Disturbances to the tundra and forest tundra environments of the western arctic. Canadian Geotechnical Journal 7:420-432.

Mackay, J.R., 1975. Freezing processes at the bottom of permafrost, Tuktoyaktuk Peninsula area, District of Mackenzie (107 C). Geological Survey of Canada Paper 75-1, Part A:471-474.

Misener, A.D., 1955. Heat flow and depths of permafrost at Resolute Bay, Cornwallis Island, North West Territories, Canada. American Geophysical Union Transcripts 36(6):1055-1060.

Morrisey, L.A., 1978. Permafrost distribution and characteristics near Schefferville, Quebec: Recent Studies. 428-433 in: Third International Conference on Permafrost (Edmonton, Alberta, 10-13 July, 1978) Proc 1: National Research Council of Canada, Ottawa. 947 p.

Morrisey, L.A., 1983. The utility of remotely sensed data for permafrost studies. 872-876 in: Permafrost: Fourth International Conference, Proceedings (Fairbanks, Alaska, 17-22 July, 1983) Washington D.C., National Academy Press. 1524 p.

Nicholson, F., 1978. Permafrost modification by changing the natural energy budget. 62-67 in: Third International Conference on Permafrost (Edmonton, Alberta, 10-13 July, 1978) Proc. 1: National Research Council of Canada, Ottawa. 947 p.

Osterkamp, T.E., 1983. Response of Alaskan permafrost to climate. 145-152 in: Permafrost: Fourth International Conference — Final Proceedings (Fairbanks, Alaska, 17-22 July, 1983) Washington D.C., National Academy Press.

Osterkamp, T.E., and Payne, M.W. 1981. Estimates of permafrost thickness from well logs in northern Alaska. Cold Regions Science and Technology, 5:13-27.

Richardson, J., 1841. On the frozen soil of North America. Edinburgh New Philosophical Journal 30:110-123.

Smith, M.W., 1984. Climate change and other effects on permafrost. 153-155 in: Permafrost: Fourth International Conference — Final Proceedings (Fairbanks, Alaska, 17-22 July, 1983) Washington D.C., National Academy Press.

Smith, M.W., and Riseborough, D.W. 1983. Permafrost sensitivity to climatic change. 1178-1183 in: Permafrost: Fourth International Conference, Proceedings (Fairbanks, Alaska, 17-22 July, 1983) Washington D.C., National Academy Press. 1524 p.

Taylor, A.E., and Judge, A.S. 1974. Canadian geothermal data collection — northern wells, 1955 to February 1974. Geothermal Series no. 1, Geothermal Service of Canada, Earth Physics Branch, Energy, Mines and Resources. Ottawa.

Taylor, A.E., and Judge, A.S. 1975. Canadian geothermal data collection — northern wells 1974, Geothermal Series no. 3, Geothermal Service of Canada, Earth Physics Branch, Energy, Mines and Resources. Ottawa.

Taylor, A.E., and Judge, A.S. 1976. Canadian geothermal data collection — northern wells 1975, Geothermal Series no. 6, Geothermal Services of Canada, Earth Physics Branch, Energy, Mines and Resources. Ottawa.

Taylor, A.E., and Judge, A.S. 1977. Canadian geothermal data collection — northern wells 1976-77, Geothermal Series no. 10, Geothermal Service of Canada, Earth Physics Branch, Energy, Mines and Resources. Ottawa.

Taylor, A.E., and Judge, A.S. 1979. Permafrost studies in northern Quebec. Geogr. Phys. Quat., vol XXXIII, no. 3-4:245-251.

Taylor, A.E., Judge, A.S., and Burgess, M.M. 1979. Canadian geothermal data collection — northern wells 1977-78, Geothermal Series no. 11, Geothermal Service of Canada, Earth Physics Branch, Energy, Mines and Resources. Ottawa.

Taylor, A.E., Judge, A.S., Burgess, M.M., and Allen, V.S. 1981. Canadian geothermal data collection — northern wells 1978-80, Geothermal Series no. 12, Geothermal Service of Canada, Earth Physics Branch, Energy, Mines and Resources. Ottawa.

Taylor, A.E., Judge, A.S., Burgess M.M., and Allen, V.S. 1982. Canadian geothermal data collection — northern wells 1981, Geothermal Series no. 13, Geothermal Service of Canada, Earth Physics Branch, Energy, Mines and Resources. Ottawa.

Taylor, A.E., Judge, A.S., and Desrochers, D. 1983. Shoreline regression: Its effect on permafrost and the geothermal regime, Canadian Arctic Archipelago. 1239-1244 in: Permafrost: Fourth International Conference, Proceedings (Fairbanks, Alaska, 17-22 July, 1983) Washington D.C., National Academy Press. 1524 p.

Taylor, A.E., Judge, A.S., Burgess, M.M., and Allen, V.S. 1986 (unpublished). Canadian geothermal data collection — northern wells and permafrost temperatures. Geothermal Series no. 14, Geothermal Service of Canada, Earth Physics Branch, Energy, Mines and Resources. Ottawa.

Thie, J., 1974. Distribution and thawing of permafrost in the southern part of the discontinuous permafrost zone in Manitoba. Arctic 27(3):189-200.

Vierech, L.A., 1973. Ecological effects of river flooding and forest fires on permafrost in the taiga of Alaska. 60-67 in: North American Contribution, Permafrost Second International Conference (Yakutsk, USSR, 13-28 July, 1973) Washington D.C., National Academy of Science. 783 p.

Washburn, A.L., 1980. Focus on Polar Research. Science 209:643-652.

Watmore, T.G., 1969. Thermal erosion problems in pipelining. 142-162 in: Proceedings, Third Canadian Conference on Permafrost. National Research Council of Canada, Technical Memorandum 96. Ottawa.

Williams, G.P., and Gold, L.W. 1976. Ground temperatures. National Research Council of Canada, Canadian Building Digest 180 (July). 4 p.

Young, S.E., 1985 (in press). Shallow ground temperature data collection for northern Canada. Earth Physics Branch Open-File Report. Energy, Mines and Resources. Ottawa.

Young, S.E., and Judge, A.S. 1985 (unpublished). A ground temperature data collection for northern Canada. McGill University Workshop (Montreal, Quebec, 8 November, 1985).

B. LIFE SCIENCES
SCIENCES BIOLOGIQUES

LIMITATIONS ON IMPACT ASSESSMENT AS A TOOL FOR 'BALANCED' DEVELOPMENT IN THE NORTH: LESSONS FROM THE BEAUFORT ENVIRONMENTAL ASSESSMENT AND REVIEW PROCESS

Rebecca Aird

Faculty of Environmental Studies, York University, North York, Ontario M3J 1P3

Level: Master's

Abstract

Environmental impact assessment (EIA) was an institutional response to a strongly felt need to alter the basis on which development decisions were being made. At opposite ends of a spectrum EIA can be viewed as an information-gathering exercise with an emphasis on substance, or as a decision-making process which involves open debate, thereby creating the opportunity to question the values and policies that underlie existing approaches to development. The way in which EIA is perceived defines the type and scope of problems addressed. Using the Beaufort EARP as a case study, this paper examines three sets of limitations on EIA as a tool for balanced development in the North: lack of planning context; constraints on scientific prediction and assessment; and distortion of public participation.

Key words: Beaufort Environmental Assessment & Review Process, Environmental Impact Assessment, Impact prediction and evaluation, public participation

Résumé

La prospective technologique (Environmental Impact Assessment) a été l'outil forgé par les autorités publiques pour satisfaire un besoin largement ressenti de modifier l'ensemble des raisons sur lesquelles se fonde la prise de décisions en matière d'industrialisation. Aux deux extrémités de son éventail d'interprétations, on peut considérer la prospective comme un effort de recueil de l'information mettant l'accent sur le fond des problèmes, ou comme un processus décisionnel fondé sur la transparence du débat, fournissant ainsi la possibilité de critiquer les valeurs et les lignes de conduite sous-tendant les méthodes actuelles d'industrialisation. La façon dont on conçoit la prospective précise le genre et l'ampleur des questions qu'on étudie. Utilisant l'Analyse de la prospective d'environnement (EARP) de Beaufort comme exemple, l'auteure examine les limitations de la science en matière de prévision, d'analyse et d'évaluation des incidences d'environnement, ainsi que le rôle du public et de l'échelle des valeurs en matière de prospective.

Mots-clés: Analyse de la prospective d'environnement de Beaufort, prospective technologique (EIA), prospective des incidences d'environnement et analyse, participation du public.

Background on EIA

Environmental Impact Assessment (EIA) was introduced as one institutional response to a perceived need to control the environmental degradation associated with development activities. Assessments within the traditional framework of welfare economics (e.g., cost-benefit analysis) were seen, by a growing segment of the population, to be incapable of satisfactorily incorporating environmental values. Via project-specific impact analysis, full disclosure and public review, EIA was to inject environmental content into development plans and increase the public accountability of decision-makers.

TABLE 1

EXPLANATION OF FIGURE

1 and 2 represent two hypothetical EIA's toward either end of the 3 dimensional spectrum defining the conduct of environmental assessment.

Assessment 1

Approach: The focus is on technical generation and interpretation of information. Some public input may be solicited upon completion of the EIS.

Scope: The main subject of investigation is the biophysical environment, although some of the implications of predicted biophysical impacts for the social and/or economic environment may be considered.

Level: The assessment is only undertaken once significant energy has been invested in designing a specific project. Site and/or design specifications may be given nominal consideration, but the assessment is mainly mitigation oriented.

Assessment 2

Approach: The public is involved early in the process in order to identify options, interests, and concerns, and to incorporate 'lay' knowledge, perceptions, and understanding. There is explicit recognition of value conflicts. The goal is to attempt to resolve these. The assessment is issue and value oriented, rather than ostensibly comprehensive and objective.

Scope: There is an explicit attempt to consider all aspects of the environment: human (social, cultural, economic, aesthetic etc.) and biophysical. The evaluation is likely to be anthropocentric, emphasizing human welfare as opposed to the intrinsic value of natural environments, or ecological integrity per se.

Level: Assessment may be undertaken at the policy, planning, or program level, before energy and interest have been vested in a particular 'solution'. There is explicit examination of needs and goals, and an effort to generate real and viable alternatives.

From Aird 1984

In current practice EIA and its variants envelop a range of processes which vary significantly in scale of project, level of application, approach to assessment, and substance or scope. The term has been applied to small, localized, clearly delineated projects for the purpose of impact mitigation, and to major regionally and nationally significant developments for the purposes of project approval, program evaluation and planning. As a process it runs the spectrum from an ostensibly objective, technical, information-gathering activity, to

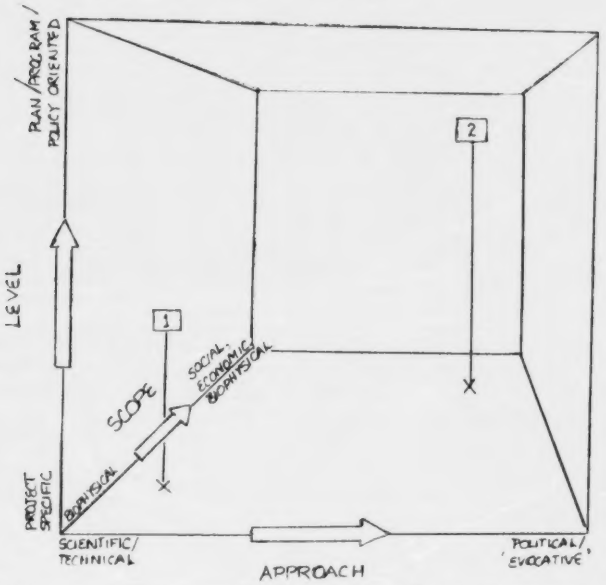


Figure 1. Three Dimensional Spectrum Defining the Conduct of EIA (see Table 1 for legend)

a public, participatory decision-making process. Substantive concerns may be limited to the natural biophysical environment, or may encompass social, cultural and economic issues. Figure 1 and the accompanying text illustrate three dimensions of variability of the process. The Beaufort Environmental Assessment and Review Process (EARP), which provides the case-study focus for the current analysis, ostensibly leans towards the non-trivial, broadly scoped, participatory style of impact assessment.

Background on the Beaufort EARP

1. The context of hydrocarbon development in the north

Hydrocarbon development initiatives in the early 1980s in the Beaufort region were influenced by a complex interaction of historical, social, ideological, economic and political factors. Only a few of the key influences can be touched on here, to illuminate the context in which the Beaufort EARP operated.

The historical and contemporary influence of frontierism is important. The dynamism created by the importation of science and technology to a new, open continent — with seemingly infinite resources and few cultural or institutional restraints — has become an intrinsic aspect of North American culture (Marx 1970). Frontierism has combined with a belief that growth in resource consumption, technological capacity, etc. is essential for quality of life, resulting in an assumption that the resources and cultures of remote areas must inevitably be sacrificed to urban-industrial expansion. As Berger (1977) so clearly perceived, the frontier mentality of Euro-Canadians is still abundantly evident in attitudes about resource exploitation in the North, in contradistinction to aboriginal people's perception of the North as homeland. Dominant notions about progress lead to assertions that oil and gas development offer northerners "new opportunities to move beyond survival" (Northern Affairs 1983), revealing a perception of Native societies as virtually acultural, trapped in a day-to-day hand-to-mouth struggle for subsistence.

In political and economic terms, the federal government had clearly recognized the strategic importance of the Arctic by the 1970s (McRobert 1986). Sovereignty issues (brought home by the voyage of the U.S. Manhattan through the Northwest Passage in 1969), a growing excitement about the resource potential of the North (fueled by the Alaska Prudhoe Bay discovery in 1968) and domestic romanticism about the development challenges of the North were fused into government policy and action (e.g., the National Energy Program) designed to spur frontier resource development.

These and a host of related attitudes and circumstances combined to give development in the Beaufort an air of inevitability and an aura of desirability in terms not only of the national interest (energy self-sufficiency) but also of the regional economy and society.

2. The Beaufort EARP

Oil and gas exploration have been ongoing in the Beaufort Sea-Mackenzie Delta region since the mid 1960s. Offshore drilling in shallow waters began in 1972, and since 1976 wells have been drilled in deeper waters. (Current activities are of course being frozen by world market prices, though the apparent potential of Gulf's Amauliguk find suggests that that company's rigs will not be long mothballed). The billion-dollar plus exploration phase (Dome *et al.* 1981) has had far-reaching impacts in the region, particularly for the coastal community of Tuktoyaktuk and the administrative centre of Inuvik. Nonetheless, decisions about exploration activities were largely being made by industry and government without public input. (Chevron, a company that had not heavily invested in the region during the tax inspired melée of the late seventies and early eighties, is the only company currently negotiating an exploration agreement in the Valley. Perhaps because of the lack of near-term development prospects, the company can afford the leisure of negotiating with the Fort Good Hope people on the terms of the agreement. However, Chevron maintains that if agreement with the community cannot be reached, it will withdraw from the North until land claims are settled.) As the probability of development in the late 1980s increased, however, the need for public review of the implications of this phase became inescapable. In July 1980, John Munro, then Minister of the Department of Indian Affairs and Northern Development (DIAND), referred the Beaufort Hydrocarbon Production and Transportation Proposal to the federal Environmental Assessment and Review Office, and ten months later an Environmental Assessment Panel consisting of seven members, all from the private sector, was established. The Panel's mandate was to identify major positive and negative developmental effects, and recommend ways of dealing with them. In other words, the terms under which the development would proceed. Not surprisingly, the desirability of and alternatives to proceeding were not seriously at issue.

Dome Petroleum Limited, Gulf Canada Incorporated and Esso Resources Canada Limited undertook responsibility for preparing the EIS (Dome *et al.* 1982) on behalf of all permit holders in the Beaufort. The Panel held hearings on both the draft Environmental Impact Statement (EIS) guidelines and on the proposed development itself. Two kinds of sessions were held: Community Sessions limited to presentations from community members and their invited representatives, and General Sessions. An intervenor funding program,

announced three months prior to the hearings on the EIS guidelines, made available a total of just over $1 million, largely to community and regional organizations. (Though controversially, the largest single recipient was a coalition of largely southern-based environmental organizations).

The proponents' seven volume EIS, completed for public review in November 1982, included analysis of drilling, production, processing and ancillary (e.g., port) facilities, as well as two alternative transportation scenarios — a large diameter pipeline and ice-breaking tankers. In response to the Panel's substantial deficiency statement on the original EIS (Beaufort Sea Environmental Assessment Panel 1983), the proponents tabled additional information including analysis of a small diameter pipeline option for a low-level production scenario. Public hearings on the proposal took place from September to December 1983. The Panel produced its final report in July 1984, with recommendations geared towards a phased approach to development, beginning with small-scale production and a small-diameter pipeline through the Mackenzie Valley.

The Beaufort EARP has been held up as a broader kind of assessment, since it was undertaken for a regional-scale development proposal (which was therefore composed of a number of relatively discreet operations and stages, each of which could be separately subjected to an impact assessment) and because plans with respect to the pace and scale of development, and the mode of transportation of hydrocarbons, were open to debate. On the down side, this allowed the proponents to waffle on some controversial issues, and to evade some lines of questioning about specific aspects of the development. For example, when asked for clarification of monitoring plans in relation to predicted impacts, Dome held that the request was "somewhat unreasonable and premature . . . [going] well beyond [what is] needed by the Panel and by anyone else at this conceptual stage" (Rick Hoos, quoted in Tull 1983). Since at that point Dome's stated time horizon for commencement of production was 1986, it seems likely that the plans had reached a greater level of commitment and detail than was apparent in the EARP.

In fact, the breadth of review was limited by the exclusion from the mandate of the key issues of regional planning and land claims. (Although the Panel recognized the relevance of both regional land use planning and land claims, these were seen to be addressed via other processes.) Moreover, ambivalence about the level of detail which the Beaufort EARP addressed created confusion. The process was initiated as a general, conceptual assessment (broad impacts and alternatives), but also entailed a more detailed, site-specific, mitigation-oriented dimension. The proponents were seeking approval in principle for the development phase, but because the review procedure for specific components of development following such approval was not delineated, there was evident tension between levels of assessment during the EARP hearings.

Constraints on EIA as a tool for balanced development in the north

1. Lack of a planning context

The logical role of EIA in the pursuit of desired land/resource use patterns has been well articulated by Richardson (1982: 7):

> In an ideal world, land use goals, policies, objectives and guidelines would be determined through the land use planning process while environmental assessment would determine the acceptability of particular projects in relation to these goals, policies, objectives and guidelines . . . and in doing so would contribute to the refinement of land use plans.

Throughout the Beaufort EARP, many intervenors expressed dismay that an impact assessment of a major hydrocarbon development proposal was being undertaken in the North in spite of the absence of a policy and planning framework for northern development. Frustration was compounded by the fact that in 1979 an EARP panel reviewing a relatively modest exploratory drilling proposal in Lancaster Sound recognized that any decision made in the absence of a planning framework would be arbitrary. That panel had recommended a moratorium on drilling until a regional plan could be prepared.

Thus, the most obvious constraint on the contribution of EIA to balanced development in the North is that the desired balance, from which land use goals and plans could flow, has not yet been functionally defined. DIAND had identified the three central elements of balanced development as the needs of northern peoples, the maintenance of ecological integrity, and development of resources (DIAND 1972), but at the time of the Beaufort EARP little had been done to clarify the relationship between these elements. Moreover, the amorphous notion of the national interest was added to the confusing melange of considerations.

TABLE 2
Some Areas of Biophysical Data Inadequacies and Uncertainty Identified by the Beaufort EARP Panel in their Final Report

1. Climatic trends over the next several decades, and the resultant effects on: ice conditions for tanker traffic; permafrost, and therefore ground stability; precipitation and therefore visibility, etc.

2. Factors controlling the growth and breakup of landfast ice (therefore preventing an assessment of the effects of artificial islands on the ice regime and consequent impacts on beluga movement etc.)

3. Benefits of reusing one track versus using new tracks for each passage of the icebreaking tankers

4. Depth of trenching required in different areas of the seabed to avoid ice scour to pipelines

5. Pipeline maintenance problems (e.g., stream erosion; channelling beneath the pipeline; thermal erosion, etc.)

6. Adequacy of pipeline leak-detection methods

7. Hydrographic charting for shipping routes

8. Potential for thaw settlement; knowledge of permafrost conditions (a prerequisite for route selection)

9. Fate of pollutants in the Beaufort Sea (movements; accumulation; degradation; biological impacts, etc.)

10. Effects of hydrocarbon accumulations in the Beaufort Sea from the release of formation water and minor spills etc.

11. Existing response capability with respect to handling toxic and hazardous waste spills

12. Distribution and occurrence of fish in some parts of the nearshore and offshore environments of the Beaufort Sea (and therefore problems with respect to the containment of dredging impacts and possible disruption of fish habitat and benthic ecosystems)

TABLE 2 continued

13. Broadly-based ecological knowledge of Arctic fish (marine, fresh water and anadromous) systems (including Arctic cod, a fish critical to the food chain); fish habitats; migration; productivity of resident species in lakes and rivers; sensitivities, etc.

14. Communication and echo location processes of marine mammals and sensitivity to various sound frequencies, and ambient sound levels (rendering unpredictable the effects of icebreaker noise on marine mammals)

15. Effects of tanker traffic on local ice regime, wildlife populations and distribution, and human travel and safety: including effects on seal dens (e.g., flooding); possibility of whales following leads made by icebreakers and becoming trapped, etc.

16. Long-term effects of air traffic noise on fauna, especially birds

17. Incremental, cumulative effects of oil production and transportation on animal populations

18. Effects of major oil spills on ecological systems and biological populations over the long term

19. Physiological, ecological and toxicological effects of oil on epontic and sub-tidal biota and hence on species at higher trophic levels

20. Seal pupping areas (distribution of dens)

21. Sea mammal distribution, movement, numbers and migration

22. Cumulative effects of tanker traffic, oil spills, icebreaking noise and activity etc. on whales: Very limited data

23. Biology and ecology of bowhead whales

24. Beluga behaviour

25. Impacts of tanker traffic on walrus

26. Seasonal distribution and ecology of many species of marine birds, including a paucity of baseline data in the Beaufort and along tanker routes

27. Cumulative and synergistic impacts due to stresses on birds in other parts of their range

28. Consequences of major oil spills on migratory birds

29. Polynyas

30. Cumulative effects of various developments on caribou, including effects of corridor development on caribou migration and behaviour (see article by Cameron and Whitten, 1982, in Tull, 1983, Appendix)

31. Caribou population dynamics

32. Caribou summer range ecology; insect relief habitat; relationship of behaviour to linear developments; behaviour of bulls during calving season

33. Sensitive habitats of terrestrial mammals

34. 'Special' areas.

2. Constraints on scientific prediction and assessment

In theory, EIA is grounded in the application of scientific methods and principles for impact prediction and analysis. This involves the identification of impacting factors and the environmental components susceptible to them, and a determination of the scope, duration and implications of both primary and higher order impacts. The substantive problems, lack of consistency, and methodological confusion that characterize impact prediction and analysis have been the subject of considerable criticism (e.g., Beanlands and Duinker 1983, Clark *et al.* 1983, Rosenberg *et al.* 1981). The Beaufort EIS is clearly illustrative of problems attributable to the lack of a sufficient data base and to methodological deficiencies, including an inadequate analytic framework. The dearth of well-defined, well-established ecological principles, and difficulties in applying ecological principles in a predictive mode, are serious overall constraints on the current practice of EIA, but demand a more detailed treatment than can be rendered here. (They are addressed in the major paper from which this paper is drawn.)

As Taylor (1979) has noted, there has been no systematic baseline biological data gathering comparable to the geological survey work that has been done in Canada. The problem of an inadequate data base is especially acute in frontier areas such as northern Canada. The life histories of many species are a mystery, and some species have not even been identified. In fact,

> most biological studies in the Northwest Territories have been designed in reaction to conflicts and crises. Short-term and short-sighted impact studies have been given precedence in funding over long-term basic research [despite the fact that] basic biological research is necessary for both management and impact purposes. (Dickinson and Herman 1979: 55)

As the Beaufort Environmental Assessment Panel concluded (1984: 86), "Canada does not have integrated, focussed policy or programs for Arctic research".

How were information inadequacies handled in the Beaufort EIS? The proponents suggested that where uncertainty surrounded an issue, they took a "conservative approach" in their impact estimations. In reality, where areas of concern were speculative (e.g., the effects of marine parasites transferred by ballast water) the proponents tended to err on the side of leniency in impact prediction (Tull 1983). Where the data base was scant the proponents often concluded that the impact of concern was unlikely to occur, thereby abdicating responsibility for further analysis or mitigation. Thus in some cases where the analysis appeared to be leading to a finding of significant impact, the proponents did not work through to the logical conclusion (Brooks 1983). On the other hand, information supporting interpretations favourable to the proponents' case tended to be emphasized (e.g., the apparent attraction of caribou bulls to elevated structures in summer) while evidence of potential negative impacts was downplayed (e.g., avoidance of pipelines by cows and calfs). There was no consideration in the Beaufort EIS of pre-impact year to year variation (e.g., in species population size). In the North in particular, such variations can be extreme and may therefore determine the severity of industry-related impacts.

The proponents made no attempt to keep track of data inadequacies, or (beyond much overused ambiguous qualifiers such as "might", "could", "possibly" and "probably") to indicate the level of confidence that could be placed in their predictions. Many of the data gaps identified in the support documents were not clearly indicated in the EIS itself (Brooks 1983). In their final report, the Beaufort EARP Panel (1984) noted a number of the more obvious data limitations on the biophysical analysis. These are summarized in Table 2.

In terms of method, though there was an attempt to provide a framework for impact evaluation in the Beaufort EIS (refer to Table 3), definitions for the severity of biological impact have come under justified criticism. As Tull (1983) has noted, a number of the component terms (e.g., regional, significant) are undefined and may vary from species to species.

TABLE 3
FRAMEWORK USED BY THE BEAUFORT PROPONENTS FOR DETERMINING THE SIGNIFICANCE OF PREDICTED IMPACTS
(from Dome *et al.*, 1982. Volume 4 Table 1-1, p. 1.3)

A MAJOR IMPACT exists when a regional population or species may be affected to a sufficient degree to cause a decline in abundance and/or a change in distribution beyond which natural recruitment (reproduction and immigration from unaffected areas) would not likely return that regional population or species, or any population or species dependent upon it, to its former level within several generations.

A MODERATE IMPACT exists when a portion of a regional population may be affected to a sufficient degree to result in a change in abundance and/or distribution over more than one generation of that portion of the population or any population dependent upon it, but is unlikely to affect the integrity of any regional population as a whole.

A MINOR IMPACT exists when a specific group of individuals of a population in a localized area and over a short time period (one generation) may be affected, but other trophic levels are not likely to be affected in a manner which is considered regionally significant, or the integrity of the population itself is not significantly affected.

A NEGLIGIBLE IMPACT exists when the degree of the anticipated biological effects are less than minor.

This made it possible for the proponents to avoid specific estimates of population impacts, thereby preventing independent scrutiny of the assessment of potential impacts. The biological definitions in the framework are also incomplete. The proponents attempt to incorporate a number of factors (e.g., size of area and duration of impact) under one category. Thus, for example, there is no category in the framework for effects on individuals of a population in a localized area over more than one generation. This masks local effects by placing them in a regional context. Therefore, possible impacts on renewable resource activities and the traditional economy of Native communities are hidden.

A related but more insidious problem with the framework is the application of arbitrarily defined geographical regions in conjunction with the ostensibly ecological use of the term 'population'. Biologically speaking, the term implies some degree of genetic isolation from other members of the species. In the Beaufort EIS the term is stripped of ecological meaning by misapplying the qualifier "regional". The regions referred to are based not on population characteristics, but rather are related to the various phases or components of the proposed development (e.g., the production site versus the transportation corridor). As a specific example, the EIS states that the Kendall Island snow goose colony may be abandoned due to disturbance. Presumably the colony is a unique population in ecological terms, but the logical conclusion that this represents a major impact is circumvented by suggesting that "the possible impact on the regional population should not exceed minor" (Volume 4: 2.20).

Another common EIA method problem, clearly evidenced in the Beaufort EIS, is the deceptive argument that the impacting factors (e.g., turbidity, salinity, nutrient load, noise) resulting from the proposed development will not exceed the limits of natural variability, and actual impacts will therefore be negligible. Thus, important differences (e.g., extent, duration, timing) between project-induced impacts and natural variation are ignored.

Finally, the Beaufort EIS blatantly exemplifies the tendency to avoid any analysis of cumulative and synergistic impacts of the various project components. Referring to the assessment matrix from Volume 1 of the EIS, for example, four minor and three moderate impacts on benthic infauna have been identified. (Impacts were rated on the assumption that mitigative measures noted in the text will be applied and will be 100% effective). There is no indication of how these add up in terms of overall impact. Despite the admonitions of the Panel (Beaufort EARP Panel, 1983), the proponents did not address this serious deficiency in their supplementary information.

Given these and other problems, the position of the Department of Fisheries and Oceans (1983: 5.6) on the Beaufort EIS seems reasonable:

> A better assessment of major impacts is required to provide a basis for effective decision making, for establishing operating conditions and mitigative measures, and for determining research and monitoring requirements.

While some of the weaknesses exemplified in the Beaufort EIS can be ameliorated through a more carefully developed analytic framework, others, such as baseline inadequacies and limitations on the predictive potential of the biological/ecological sciences, represent fundamental constraints. Moreover, as purveyors of the EIS, the proponents are unlikely to assume a rigorous, critical approach to assessment. Ultimately, EARP panels undoubtedly lack the political strength to continue to return a verdict of inadequacy on the EIS of a proposal which has been implicitly sanctioned through other government policy and action.

3. Constraints on the effectiveness of public participation

Opportunities for public participation in EIA have increased since the inception of the process. In the federal EARP alone, compare the one day public meeting accompanying the Point Lepreau review with the three months of hearings for the Beaufort proposal. It is debatable, however, whether the effectiveness of participation has also increased. It is often argued that public participation is merely used to legitimate decisions that have already been made (e.g., Smith 1983). Conditions which minimize the 'radical' potential of participation in EIA include: Circumscribed context and opportunities for public participation; negation of the potential for alternative forms of development; a focus shifted towards the extraction of concessions and rewards; the use of ostensibly objective measurements of costs and benefits to avoid value-based conflicts.

Ironically, in the North, where the population is small, the number of public hearings is relatively large. To 1981, approximately 100 public review hearings had been held (Waddell, 1981). There have been six sets of hearings associated with Yukon/Mackenzie Valley pipeline proposals alone, not including the Beaufort EARP. To individuals concerned about the basic thrust of industrial development, hearings held subsequent to the Berger Inquiry appeared redundant. Thus apathy has developed towards participation in project-specific review forums. 'Burn out' of politically active individuals in the Mackenzie Valley and Delta communities is a real problem.

The context for participation in the Beaufort EARP was set by the Panel's mandate — which did not incorporate a number of issues of a critical long-term nature (land claims

and comprehensive land-use planning) — and by the implicit assumption that the question under review was not whether hydrocarbon development should proceed, but how. Thus, advocates of fundamental alternatives to a socio-economic structure created by externally-controlled non-renewable resource development find no meaningful voice in forums such as the Beaufort EARP. Their interests play no part in the definition of needs and problems (e.g., the 'need' for Canadian energy self-sufficiency via increased domestic supply of non-renewable energy resources; the 'need' to develop a stronger wage economy in the North) to which Beaufort hydrocarbon development is the proposed solution. For example, the fact that the attitudes of native peoples, and of northerners in general, towards employment are very different from the Euro-Canadian norm was never adequately addressed in the Beaufort EIS, nor the fact that the social organization of work is radically different (in terms of rights, power, prestige, ownership, units of production etc.). The question of how the testimony of different intervenors at the Beaufort hearings was to be compared and balanced was never made explicit.

To summarize, ostensibly new, participatory decision-making processes such as EIA are superimposed on old structures and institutions. The inertia imbedded in these processes due to institutional and ownership structures, and consequent inequities in the accessibility and control of information and technology, tend to be conveniently ignored. Ultimately, there may be no future for lifestyles based on wildlife harvesting given the priorities of industrial society. Roughshod treatment of 'minority' or 'local' interests is legitimized by reference to the 'national interest'.

Conclusions

In application, EIA reflects the unresolved balance between science and values in decision-making, and a related tension between reductionist analysis and an 'organic' or synthetic perspective. These tensions result from divergent expectations. EIA can essentially be viewed as an information-gathering exercise with the emphasis on substance, or a decision-making process which involves open debate, and therefore the possibility for questioning the values and policies that underlie existing development patterns. A related set of opposing perceptions revolves around the technocratic ideal of EIA as a contribution to project management versus the more radical perspective that EIA may contribute to a fundamental re-orienting of the criteria and framework for urban-industrial development. In either sense (as a tool for mitigation or as a decision-making process), popular perceptions of the potential of scientific prediction and assessment in EIA are in need of revision. The expectation of a comprehensive, definitive description of future environments as modified by proposed projects must be foregone.

In the North, where consensus on the desired future shape of the society and economy clearly does not exist, and where local, regional and national interests on many issues are divergent, attempts to apply a process like EIA create confusion and frustration as various parties strive to mould the process to their interests. EIA may reveal the need for public debate about societal goals and the policies and plans that should flow from them, but it is not in itself an appropriate forum for such debate. Until significant strides have been made — through such processes as land claims and regional planning — in reshaping the balance of power and defining desired goals, EIA cannot serve as a tool for ensuring 'balanced development' in the North.

Acknowledgments

The contents of this paper are drawn largely from my major paper for the degree of Master of Environmental Studies at York University, Downsview, Ontario. Opportunity for direct research on the Beaufort EARP in the Mackenzie Delta in the spring of 1983 was made possible by a Northern Scientific Training Grant from the Department of Indian Affairs and Northern Development. I'd like to thank Jack Ellis and Martin Lewis for their assistance in taking advantage of that opportunity. Audrey Armour provided constant substantive and moral support throughout my studies on EIA at York. In all work related to the Beaufort EARP and northern development issues in general, the guidance, insights, and encouragement of fellow student David McRobert were invaluable.

References

Aird, Rebecca. September 1984. Science, values and public participation in environmental impact assessment: a critical perspective. Unpublished. Major paper, Faculty of Environmental Studies, York University, Downsview, Ontario.

Beanlands, Gordon E. and Duinker, Peter N. 1983. An ecological framework for environmental impact assessment in Canada. Institute for Resource and Environmental Studies, Dalhousie University, Halifax, Nova Scotia.

Beaufort Sea Environmental Assessment Panel. 1984. Final report on Beaufort Sea hydrocarbon production and transportation. Federal Environmental Assessment and Review Office, Report #25.

_____. 1983. A statement of deficiencies on the environmental impact statement for hydrocarbon development in the Beaufort Sea-Mackenzie Delta Region. Federal Environmental Assessment and Review Office.

Berger, Thomas R. 1977. Northern frontier, northern homeland: the report of the Mackenzie Valley Pipeline Inquiry. 2 Volumes. Toronto: James Lorimer and Company.

Brooks, David. February 1983. Beaufort Sea alliance submission on deficiencies in the environmental impact statement. In the interim compendium of written submissions to the Beaufort environmental assessment panel on the Dome, Gulf and Esso EIS. Vancouver: Federal Environmental Assessment and Review Office, Pacific Region.

Clark, Brian, Bisset, Ron, and Tomlinson, Paul. 1983. Post development audits to test the effectiveness of environmental impact prediction methods and techniques. Final Report. Department of Geography, University of Aberdeen, Aberdeen, Scotland.

Department of Fisheries and Oceans. December 1983. Position statement on the Beaufort Sea hydrocarbon production proposal. Prepared for the Beaufort Sea Environmental Assessment Panel.

Department of Indian Affairs and Northern Development. 1972. Canada's North: 1970–1980.

Dickinson, D.M. and Herman, T.B. 1979. Management of some terrestrial mammals in the Northwest Territories for sustained yield. Prepared for the Science Advisory Board of the Northwest Territories.

Dome Petroleum Limited, Esso Resources Canada Limited, and Gulf Canada Resources incorporated. 1982. Environmental Impact Statement — Hydrocarbon Development in the Beaufort Sea-Mackenzie Delta region. 7 Volumes plus Supplementary Information. Calgary: Dome Petroleum Limited.

_____ 1981. Hydrocarbon development in the Beaufort Sea-Mackenzie Delta Region. Calgary: Dome Petroleum Limited.

Marx, Leo. 1970. American institutions and ecological ideals. Science Volume 170: 945–52.

McRobert, David. May 1986. Northern political development and control of natural resources: a survey of the issues. Unpublished. Osgoode Hall, York University.

Northern Affairs Program. 1983. Beaufort Sea hydrocarbon exploration — a federal perspective. Ottawa: Department of Indian Affairs and Northern Development.

Richardson, Nigel. 1982. Land use planning, regional planning and environmental assessment: a preliminary review of the issues. Prepared for

the Beaufort Sea environmental assessment panel. Vancouver: Federal Environmental Assessment and Review Office, Pacific Region.
Rosenberg, D.M., Resh V.H. et al. 1981. Recent trends in environmental impact assessment. Canadian Journal of Fisheries and Aquatic Sciences. 38: 591-624.
Smith, L. Graham. 1983. The evaluation of public participation in water resources management: A Canadian perspective. In Frazier, John W., Epstein, B.J., Bardecki, M. and Jacobs, H., eds. Papers and Proceedings of Applied Geography Conferences. Volume 6: 235-44.
Taylor, Mark E. 1979. Ecology and Governments in Canada. In Leiss, William, ed. Ecology Versus Politics in Canada. Toronto: University of Toronto Press.
Tull, C.E. November 1983. The quality of the EIS and the need for further hearings. Presented to the Beaufort Sea environmental assessment panel on behalf of the Beaufort Sea Alliance. Inuvik.
Waddell, Bruce K. 1981. A survey of public hearings in Northern Canada. Ottawa: Northern Affairs Program, Department of Indian Affairs and Northern Development.

SOLIFLUCTION AND ITS INFLUENCE ON VEGETATION AND STREAM WATER CHEMISTRY IN SMALL PERMAFROST BASINS, AXEL HEIBERG ISLAND, N.W.T.

C. Allan[1], S. Schiff[2], D. Pierson[3], M. English[4], M. Ecclestone[5] and W.P. Adams[5]

[1]*Watershed Ecosystems Programme, Trent University, Peterborough, Ontario K9J 7B8*
[2]*Department of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1*
[3]*Division of Hydrology, University of Uppsala, Sweden*
[4]*Department of Geography, Wilfrid Laurier University, Waterloo, Ontario N2L 3C5*
[5]*Department of Geography, Trent University, Peterborough, Ontario K9J 7B8*

Level: C. Allan, Master's

Abstract

The chemistry of three ephemeral streams which drain into a small, naturally acidified lake located on Axel Heiberg Island (79° 25′N, 90° 35′W) in the Canadian Arctic Archipelago, was examined during the snowmelt in 1984 and 1985. These streams are typical of those which develop during the snowmelt season in the High Arctic. Their drainage areas range from 0.08 to 0.22 ha, they are situated in an area of continuous permafrost.

Spatial differences in stream water chemistry were large with average specific conductance values differing more than five fold (75–600 uS^{-1}) and pH values varying by more than 2.7 units (3.8–6.5) over a distance of less than 100m. Soil stratigraphy generally consisted of a shallow, brown, poorly developed cryosol underlain by a grey-black, highly acidic cryosol that extended to the bottom of the active layer. Disturbance of the upper soil horizons by solifluction, which allowed meltwater to contact the lower soil horizon, appears to be responsible for the observed spatial variation in stream chemistry.

Preliminary analysis of vegetation data indicates coverage and species assemblage differences between solifluction scarred and unimpacted basins. Vegetated slopes appeared to export more nutrients (total phosphorus and total organic nitrogen), than non-vegetated slopes.

Key words: Solifluction, vegetation, percent coverage, species composition, stream chemistry

Résumé

Les auteurs ont effectué l'analyse chimique de l'eau de trois ruisseaux temporaires qui se jettent dans un petit lac naturellement acidifié de l'île d'Axel Heiberg (par 79°25′ de lat. N. et 90° 35′ de long. O.) dans l'archipel arctique, lors de la fonte des neiges en 1985 et 1986. Ces cours d'eau sont le type même de ceux qui prennent naissance lors de la fonte des neiges dans l'Extrême-Arctique. Leur bassin de ruissellement couvre de 0,2 à 5 ha, dans une région de pergélisol.

Les différences de composition chimique entre les eaux de ces ruisseaux étaient importantes; leur conductance allait du simple au quintuple (de 75 à 660 μS^{-1}), et leur pH différait de plus de 2,7 unités (de 3,8 à 6,5) à moins de cent mètres de distance. Le profil du sol comprenait en général une couche superficielle de sol brun peu évolué, recouvrant un horizon gris-noir fortement acide rejoignant la base de la couche active. Il semble que la variabilité de la composition chimique de ces eaux voisines soit due au bouleversement des horizons pédologiques supérieurs par la solifluxion qui met les eaux de fonte des neiges en contact avec la couche sous-jacente.

L'analyse préliminaire montre qu'il existe des différences entre la couverture végétale des bassins travaillés par la solifluxion et celle des bassins non bouleversés, ainsi qu'en matière de diversité des espèces. Les pentes couvertes de végétation semblent perdre plus de nutriments (phosphore total et azote organique total) que les pentes non couvertes.

Mots-clés: Solifluxion, végétation, pourcentage de couverture végétale, diversité des espèces, composition chimique des eaux de fonte des neiges.

Introduction

A vast number of variables, including biologic structure and diversity, geologic heterogeneity, climate and season control the flux of both water and chemicals through an ecosystem. Chemicals circulate from nonliving to living components of an ecosystem in several interwoven biogeochemical cycles. Ecosystems continually lose or gain matter to and from other ecosystems and the biosphere as a whole and, therefore biogeochemical cycles are vital to the maintenance of the system (Likens *et al.* 1977).

High arctic ecosystems are subject to one extreme of the climatic continuum found on our planet. Besides extreme cold

and drought, these ecosystems are subject to wind shear because of their open exposure and are underlain by frozen ground (permafrost). All these extreme climatic or climate-induced variables interact in a dynamic fashion to influence the biogeochemical cycles which occur in these ecosystems.

Research parties from Trent University have been visiting the Expedition Fiord area in west-central Axel Heiberg Island since 1983 (see figure 1). The purpose of these expeditions has been two fold; to continue the long term mass balance study of the glaciers in the area, and to conduct a combined limnologic-terrestrial study of a naturally acidified high arctic lake system (Allan 1986, Allan *et al.* 1985 and Pierson *et al.* 1985). This paper will treat some aspects of the terrestrial study that are perhaps unique to the high arctic and this particular ecosystem.

From preliminary water analysis results from the 1983 season, it became apparent that Colour Lake and some of its seasonal snowmelt inflow streams were acidified (ca. pH 3.65). The absence of any industry and the unlikelihood of substantial influence of anthropogenic airborne acid precursors at this latitude, led us to suspect a geologic source for this acidification. Sediment porewater analysis from Colour Lake (Schiff, unpublished data) and streamwater chemistry results (Allan *et al.* 1985), confirmed this belief. The oxidation of pyrite-containing shales, which leads to the production of insoluble iron oxides and sulphuric acid, is believed to be the acidifying mechanism.

$$FeS_2 + 3.75\ O_2 + 3.5\ H_2O = Fe(OH)_3 + 4\ H + SO_4^{-2}$$

(Drever 1982)

Continued sampling of the streams in the Colour Lake basin indicated that some streams were highly acidified (pH 3.5 or lower) while others, only some tens of metres away were quite neutral (pH 6.5). It was apparent that the more severely acidified basins appeared to be influenced by solifluction and thaw slumping. The vegetation of the acidified basins also appeared to differ from undisturbed basins. A soil, water and vegetation sampling program was undertaken to assess both the spatial variability in vegetative cover and composition, and streamwater and soil chemistry within the Colour Lake basin. The working hypotheses stated that disturbances of the upper soil horizons by solifluction and thaw slumping would expose underlying acidic soils. The exposure of these soils would increase soil meltwater contact and influence stream water chemistry. Both the disturbance and possibly the exposure of acidic soils would lead to differences in vegetative cover and species composition between basins.

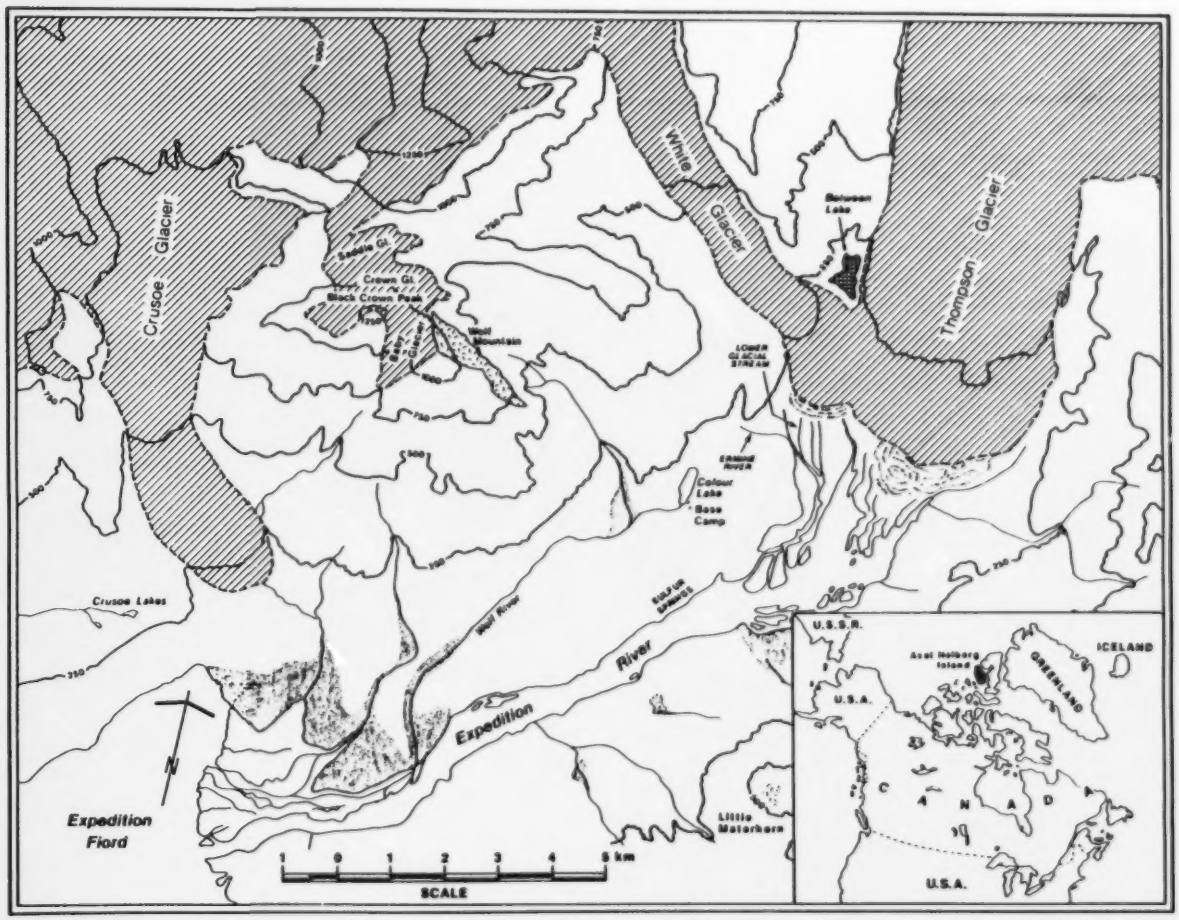


Figure 1. Expedition Fiord area, Axel Heiberg Island (79°N, 90°W)

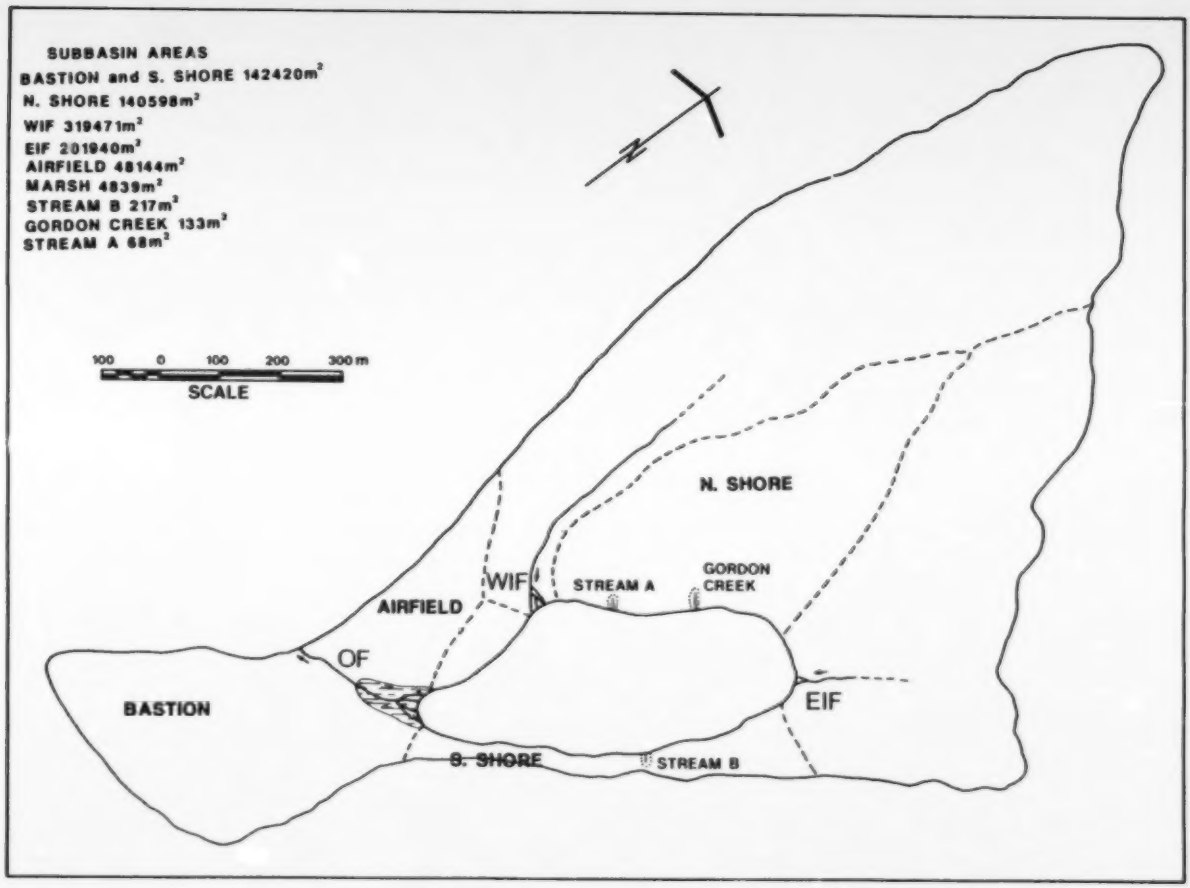


Figure 2.Colour Lake Catchment.

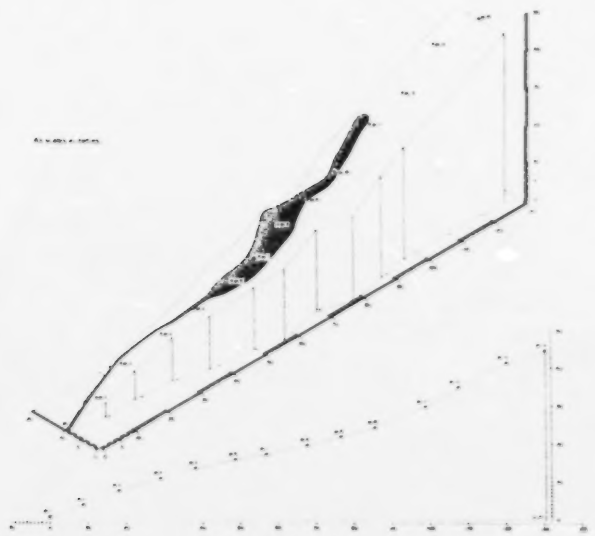


Figure 3. Gordon Creek Basin 1985.

Study Area

The 80 ha Colour Lake catchment is not glacierized today but was probably occupied by a side arm of the White Glacier during the last major glacial advance in the area (ca. 10000 YBP). The location of the three subbasins of concern here is given in figure 2, and individual basins are depicted in figures 3, 4 and 5. The physiographic indices of each catchment are given in Table 1.

The Colour Lake catchment is located in the axial portion of the Sverdrup Basin, where the total accumulated thickness of strata exceeds 8000 m. With the exception of Upper Paleozoic anhydrite evaporites (found in Stream B basin), the strata underlying each basin consist of clastic sediments (sandstones, siltstones and shales with minor intercalations of carbonitic rocks, conglomerates and coal), which range in age from Triassic to early Tertiary. Tectonic movements in the early Tertiary resulted in strong folding and faulting of the area, and were accompanied by intrusions of Upper Paleozoic evaporites (Fricker 1963a, 1963b; Krank 1963).

The climatology of the Expedition Fiord has been reported in Muller (1963), Muller and Roskin-Sharling (1967) and Ohmura (1981). The mean annual temperature for nearby Eureka (80°N 85°W), is −19.4°C with a mean wind speed of 11.6 kph and a mean total precipitation of 58.4 mm of which 22.4 mm falls as rain. Eureka's weather has been found to give a reasonably close approximation of that in Expedition Fiord (Blatter 1985).

The snowcover in the Expedition Fiord area is generally thin (5–50 cm water equivalence, (w.e.)), with numerous exposed ridges. Much of the land surface is bare at the end of winter and a great deal of the accumulated snowpack is found in hollows and lee locations (Woo 1982). The Gordon Creek, Stream A and Stream B basins are examples of such hollows which fill with a similar amount of snow each year. Stream B basin collects the most snow, ca. 30 cm w.e. followed by Gordon Creek c.a. 9 cm w.e. and Stream A basin c.a. 4.5 cm w.e. (Allan *et al.* in prep.).

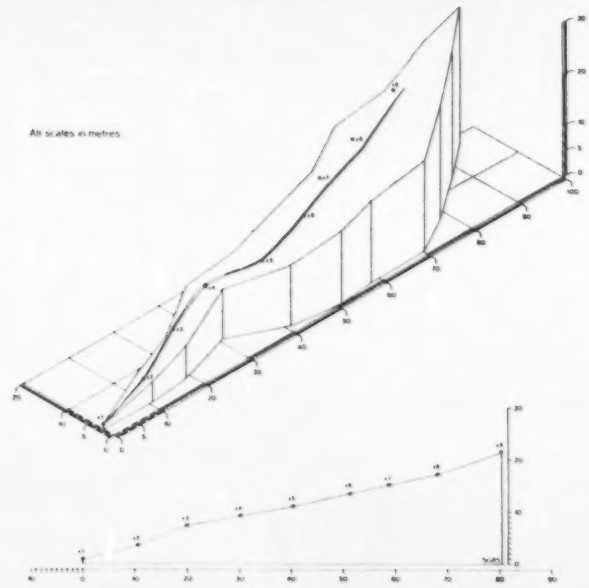


Figure 4. Stream A basin 1985.

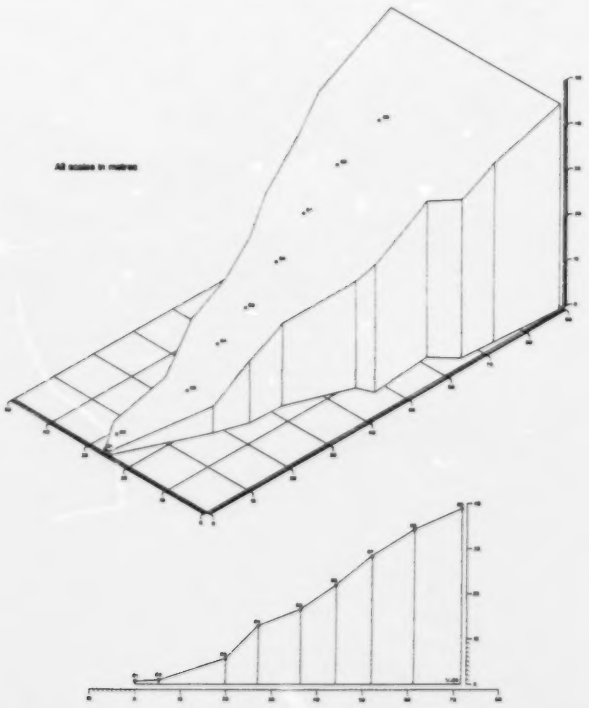


Figure 5. Stream B basin 1985.

The Expedition Fiord snowpack begins to ablate in late April during which time the ground is frozen and no infiltration is possible. The 24 hour input of solar radiation at this time contributes to a quick (1–2 week) melt and an overland flow situation. A thick ice lens often develops at the base of the deeper snowpacks as meltwater encounters the insulated frozen ground. Strong diurnal melt cycles occur during this period. Peak flows of streams on opposite sides of the Colour Lake catchment are offset by ca. 12 hours because of shading by the mountainous terrain. During late May to July the thawing ground leads to saturated soils. Small amounts of precipitation result in saturated overland flow. During this period the small snowmelt streams generally dry up (including the study basins). The peak period for wet precipitation is July–September at which time the thin active layer is at its deepest (ca. 60 cm.). The thin, coarse, soils combined with the steep slopes of the area permit rapid throughflow of even small amounts of precipitaton. During late August–September precipitation often occurs as snow. Wet precipitation or snowmelt at this time infiltrates into the soil where it can freeze, delaying runoff, often until the following spring.

Permafrost underlies each basin to a depth of 600 m+. Soils in the study basins can be generally classed as cryosols. Ridge tops and steep slopes can be classified as block slopes and are deficient in organic matter with large angular siltstone scree covering a dry light-coloured, gravel-dominated regosolic static cryosol (Canada Soil Survey Committee 1978, Tedrow 1977). More gentle slopes and valley bottoms are dominated by static and turbic forms of orthic, brunisolic and gleysolic cryosols. In some locations, solifluction lobes have allowed vegetation colonization of otherwise barren slopes. Solifluction deposits in the area often have a crude stratigraphy, perpendicular to the slope, in which organic-rich layers are overlain by more mineral-dominated layers. These buried organic deposits are the result of a solifluction lobe overriding and burying downslope tundra vegetation. The solifluction disturbances have also exposed deeper mineral soils which underlie the poorly developed organic horizons in several areas (particularly in the Gordon Creek basin). Vegetation coverage in the various catchments varies from 0% on exposed block slopes to 100% in late melting snow-filled hollows. The general gradation of each basin is from unvegetated dry block slope at the basin apex to densely vegetated *Cassiope* and *Dryas* dominated hummocky ground at the outlet. Soils in the hummocky areas show strong stirring patterns indicative of cryoturbation. Soils in this portion of the basin often have a gleyed, mottled, appearance as a result of the relatively high moisture content in these areas (particularly in Basin B). Arid soils in the basins often contain salt encrustations of sulphates (Ca and Mg) on the undersides of larger material.

Methods

Hydrologic

The Gordon Creek and Stream A catchments were hydrologically gauged to define the duration, timing and quantity of the spring runoff. The diffuse nature of the Basin B outflow made any discharge measurements impractical. Volumetric discharges for the other two basins were obtained by pressing a plastic bag into the stream channel for a measured time period and then determining the volume of water

with a graduated cylinder. Several measurements were made daily and linear interpolation was used to fill in periods between measurements.

Water sampling and analysis

Water samples were collected in clean acid-washed plastic bottles. Samples were withdrawn by placing the bottle in the stream channel in such a manner as not to disturb stream channel sediments. One 250 ml bottle was collected for major ion (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, SO^{-2} and Cl^{-}) and nutrient (total phosphorus (PPUT) and total kjeldahl nitrogen (TKN)) analysis. A 50 ml replicate sample was filtered on site with a Schlecher and Scnell Antila filter system through pre-rinsed Whatman GFC glass fibre filters (pore size 1.2 μm) to determine the dissolved phosphorus fraction (TFP). A second 50 ml sample was collected for determinations of pH and specific conductance. Specific conductance was determined with a KCl standardized Barnes Hind Conductance Bridge and corrected to 25°C. A Fisher Acumet Model 602 digital pH meter standardized to buffers of pH 3 and pH 7, was used to determine pH. Specific conductance and pH determinations were made within 24 hours at the Colour Lake Base Camp. Major cations (Ca^{+2}, Mg^{+2}, Na^{+} and $K^{\pm}$) were determined by atomic absorption at Trent University (Stainton *et al.* 1977). Major anions (SO_4^{-2} and Cl^{-}) were determined at the Canada Centre for Inland Waters, Burlington, Ontario, by ion chromatography (Small *et al.* 1975). PPUT and TKN determinations were performed at the Ontario Ministry of the Environment (OME) laboratory, Rexdale, Ontario, (OME 1981). Particulate phosphorus fractions were determined by subtracting replicate sample TFP values from PPUT values.

Temporal changes in specific conductance were recorded in situ in Stream A and Gordon Creek. Conductivity probes were placed in the stream channel and conductivity measurements were recorded on battery powered strip chart recorders. The instruments were calibrated daily with standard KCl solutions which were kept at 0°C, the temperature of the meltwater streams. The conductivity data were also used to help estimate the start and end of daily discharge.

Soil analysis

Physical and chemical analyses of the soil types were undertaken to explain differences in interbasin meltwater chemistry and possible vegetation differences. Soil pH and specific conductance determinations were made on soil cores extracted from the upper 5 cm as well as at depth in the soil profile. The fresh soil samples were analysed for pH in a 2:1 v/v 0.01 N CaCl solution (Peech 1965), and for specific conductance in a 2:1 v/v deionized water in soil solution. Soil pits were excavated at several locations within the study basins and samples were collected for grain size, moisture content, bulk density, organic content (OG), cation exchange capacity (CEC), and total and exchangeable chemical analysis for N, P, Ca, Mg, Na, K, Mn, Al and Fe. OG, CEG, and total exchangeable determinations were made at the soil laboratory, Great Lakes Forestry Centre, Sault Ste. Marie, Ont., generally following the methods outlined in Black *et al.* (1965). Soil moisture content, bulk density and grain size analyses were conducted as outlined in Briggs (1981). Frost depth was determined by manually driving a steel rod into the ground until frozen material was encountered. Three measurements were conducted at each site.

Vegetation analysis

Each sub-basin was sampled in a stratified random manner for per cent vegetation cover as well as species presence or absence. At each site, per cent coverage was determined by laying a clear plastic sheet over the sample site and tracing the outline of the vegetation. The plastic sheets were then weighed and the outlined areas were cut out and weighed separately. The percent coverage was determined by the weight of the vegetation outline/weight of total sheet × 100. The presence or absence of a plant species was recorded at each site. Species identifications were made from preserved specimens by Ms. J. Horne of the Botany Department, U. of Toronto, Mr. H. Williams, Millbrook, Ontario, and the authors. Sources utilised in keying out specimens included Porsild (1964) and Polunin (1959).

Results

Stream hydrology and chemistry

Hydrographs for Stream A and Gordon Creek are presented in figure 6. These basins had no channelized flow after June 6 although subsurface flow may have occurred later in the season. Basin B flowed intermittently until late June. *In situ* measurements of conductivity are given in figures 7 and 8. Significant interbasin and diurnal temporal variation in stream conductance is indicated. Stream chemistry results are presented in Tables 2, 3 and 4. Significant differences in mean concentrations for all chemical parameters, except Cl^{-}, F^{-}, and particulate phosphorus, exist between the various basins (Scheffe's multiple range test $p = .05$, Tables 2, 3 and 4). Differences in specific conductance, pH, SO_4^{-2} and Ca^{+2} are particularly evident when comparing Gordon Creek Subbasin with the Stream A and B basins, see figure 10. Generally, interbasin differences in the export of weathered crustally-derived ions such as SO_4^{-2}, Ca^{+2} and K^{+}, are greater than those of mainly oceanic-derived ions such as Na^{+} and Cl^{-}. The solifluction-impacted Gordon Creek basin appears to export substantially more crustal

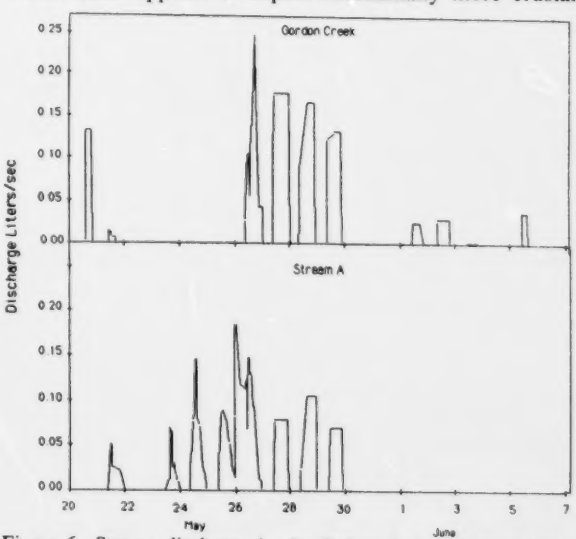


Figure 6. Stream discharge in the Colour Lake drainage basin Spring Snowmelt 1985.

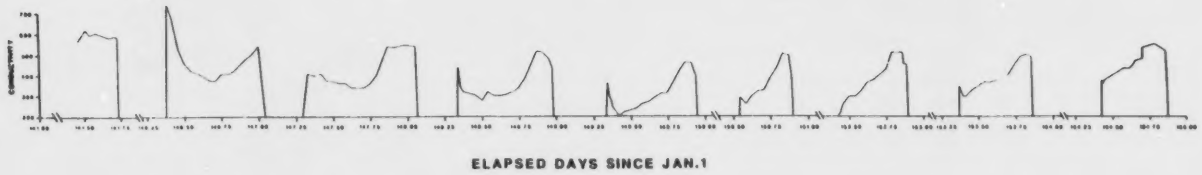


Figure 7. Gordon Creek *in situ* temporal conductivity values 1985.

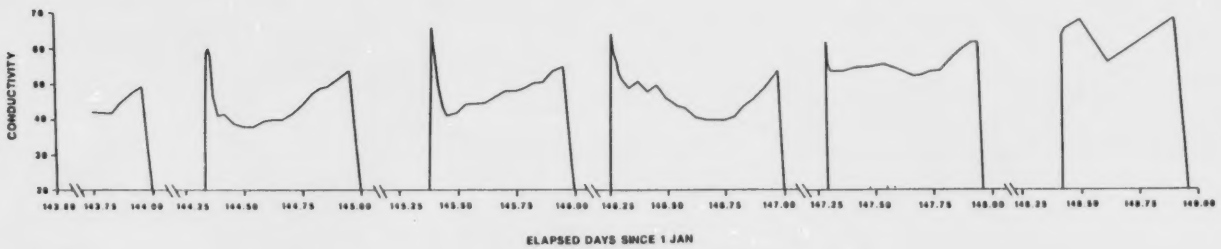


Figure 8. Stream A *in situ* temporal conductivity values 1985.

material than the other two basins. Conversely, nutrient export (PPUT, FP, DP and TKN), from the undisturbed Stream A basin appears greater than from the other two basins, see Tables 2, 3 and 4, figures 11, 12.

Soil chemistry

Permafrost depths are reported in Tables 5, 6 and 7. There appear to be no significant differences in permafrost depth between the various basins. Surface soil pH and conductivity values are presented in figures 13, 14 and 15. Soil pit total and exchangeable chemistry data are presented in Tables 8 and 9. The underlying and exposed mineral soil horizons appear to have significantly higher H^+ and conductivity values, see figure 16. The other chemical properties of the soil horizons are much harder to interpret with the overlying brown organic horizons often having higher exchangeable and total values than the underlying deposits. The thin Arctic Brown soil types appear to have slightly higher total Ca and Mn values while having lower in K, Fe and Al values in relation to the underlying gray silt-loam soils. Basin B's coarse turbic cryosols appear to have lower total N, K, and Mg values while having higher total P, Ca, Fe, and Na values than the Stream A and Gordon Creek basin soil types. Basin B's gleyed soils had high Na, Fe and Mg values when compared to the other two basins' soils. Exchangeable values were quite variable. Different locations within each basin appear to have different chemical properties irrespective of soil type. The thin Arctic Brown soil types appear to have higher exchangeable Ca and Mn values and lower Al and S values. Basin B's coarse turbic cryosols appear to have lower exchangeable P, K, Mg, Fe, Mn, Al and organic content values than the Stream A and Gordon Creek basin soil types. Basin B's gleyed soils had lower exchangeable K, Mg, and organic content values but much higher exchangeable Fe, Mn, Al, Na, and S values than soils of the other two basins. The differences in stream water chemistry cannot be totally explained by differences in soil type.

Vegetation analyses

The $\bar{x}$ and total number of species present at each site and per cent cover results are given in Table 8. There is a great deal of variation in per cent cover within each basin. There was no significant difference in per cent cover between basins (Scheffe multiple range test $p = .05$). Gordon Creek basin has significantly fewer species present at each site than Stream A or Stream B basins, (Scheffe multiple range test $p = .05$). There was no significant difference in the number of species present at each site when Stream A basin was compared with Stream B basin. The frequency of occurrence of each species within each basin is presented in Table 8. *Cefraria nivalis, Pedicularis lapponica, Polygonum viviparum, Dryas integrifolia* occurred more often in the Stream A basin than the Gordon Creek basin, (Chi square $p = .05$). *Cladonia cornufa* occurs more often in the Stream B and Stream A Basins than the Gordon Creek basin,

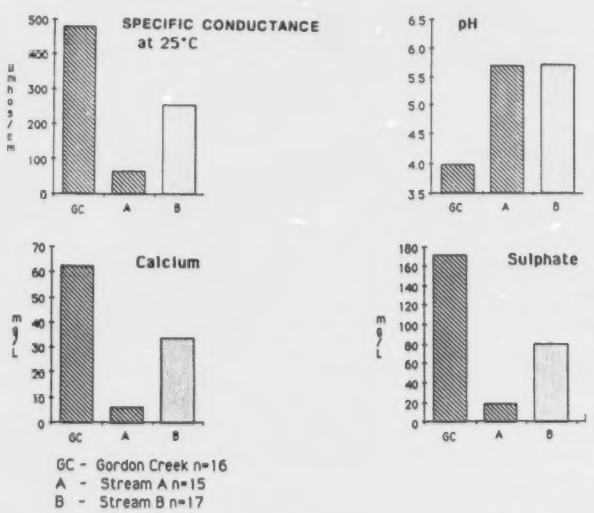


Figure 9. Mean streamwater concentration during snowmelt 1985.

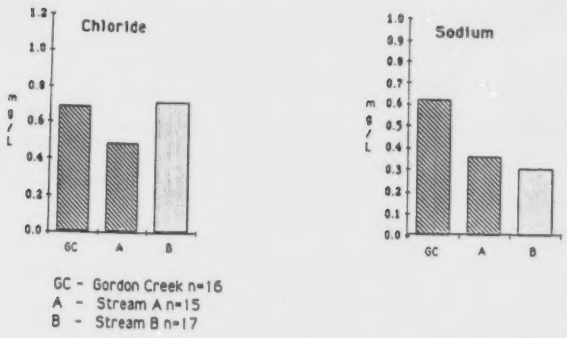


Figure 10. Mean streamwater concentrations during snowmelt 1985.

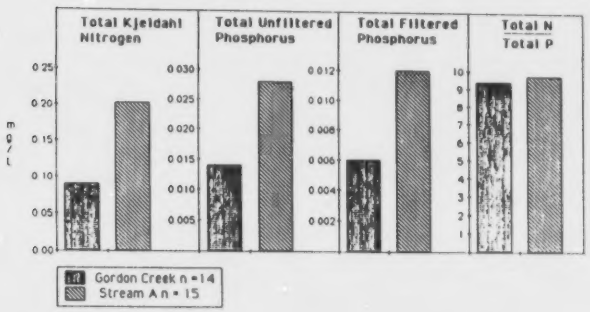


Figure 11. Mean streamwater nutrient concentrations snowmelt 1985.

(Chi square p = .05). Stream B's *Dryas integrifolia* frequency of occurrence was greater than Stream A, (Chi square p = .05). The small number of occurrences of several of the species invalidates any statistical test for differences in frequency of their occurrence between basins.

Discussion

The hydrographs show that streamflow undergoes large variations as a result of snowmelt inputs varying diurnally in accordance with the changing position of the sun (see figure 6). Thus the timing of the diurnal streamflow is determined by basin aspect. Daily melt and liquid water storage were not sufficient to sustain discharge throughout the entire day. Discharge from all basins ceased soon after the accumulated snow within them had melted.

There are large differences in water quality between the three study basins. Most notable is Gordon Creek which is strongly acidic with hydrogen ion concentrations approximately 1–4× higher than the other streams (Table 2, 3 and 4, figures 10 and 11). Sodium and chloride, two conservative ions, generally of oceanic origin, have similar concentrations in the three streams (see figure 10), indicating the importance of terrestrial processes in influencing stream chemistry. The chemical differences are greatest between the Gordon Creek and Stream A basins which are on the same hillslope and within tens of metres of each other. The major difference between the two basins is the presence of a solifluction disturbance which affected ca. 52% of the Gordon Creek basin area. The mudslide, in addition to disturbing the soil profile, also removed and buried a large portion of the basin's vegetative community. The Stream B basin is the site of an older, large, solifluction disturbance that has exposed some of the underlying sedimentary parent material. A small ultrabasic anhydryte intrusion is also present in the basin and it has been largely revegetated.

It was first postulated that differences in active layer depths might account for some or all of the interbasin variation in streamwater chemistry. It was believed that the presence of a deeper active layer would allow increased soil meltwater contact time which would alter the water chemistry of the basin. The small differences in active layer between basins do not appear to explain such large scale chemical variations.

This led us to the conclusion that local variations in basin soils and/or surficial geology were the major cause of the dissimilar stream chemistries. The results of the soil surface pH and conductance analyses clearly show patterns of low pH and high conductivities associated with the solifluction scar in Gordon Creek, (Figures 13 and 14). This is particularly apparent where the stream channel has eroded deeply into the soil profile. The undisturbed Stream A basin has relatively neutral pH and low conductivities. These data clearly indicate that the greater ion concentrations and lower pH values in the Gordon Creek water result from differences in soil pH which appear related to the solifluction disturbance.

Profiles (of pH and conductance from representative soil pits located in the Stream A and Gordon Creek basin) show that

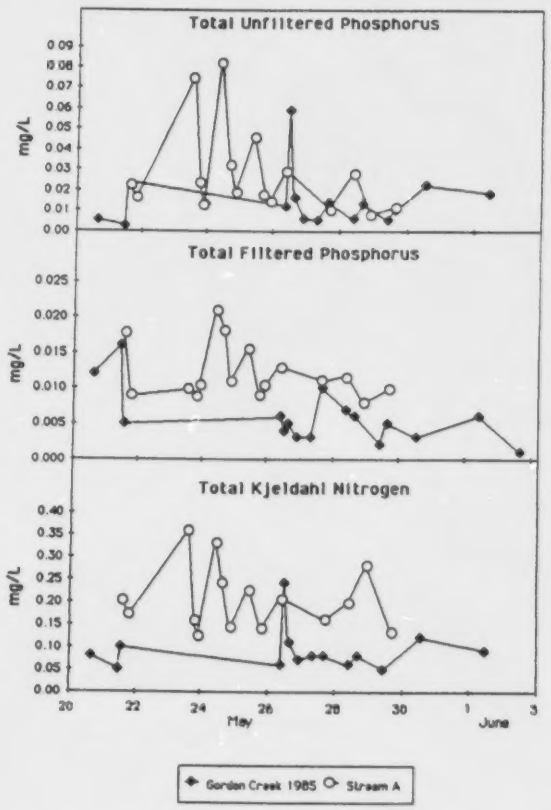


Figure 12. Temporal changes in the nitrogen and phosphorus concentrations of Gordon Creek and Stream A during 1985 runoff.

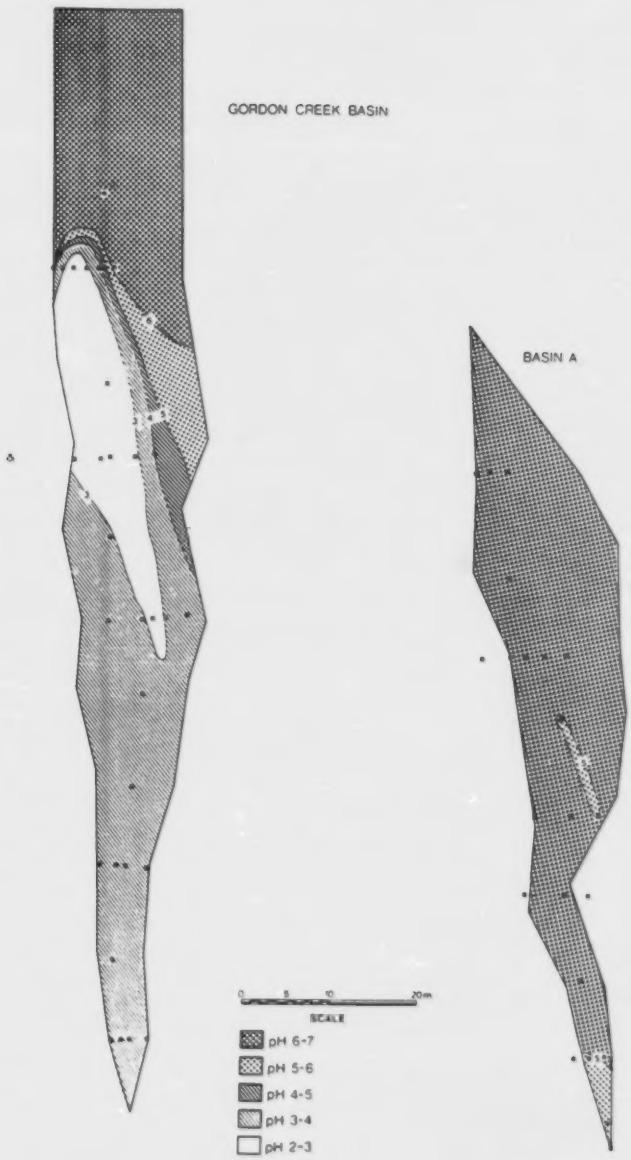


Figure 13. Surface soil (0–5 cm) pH 1985.

in areas not affected by solifluction, the soil stratigraphy in both basins shows the same pattern; a thin brown moderately organic soil of pH 5.0–5.5 and low conductance is underlain by a grey-black acidic soil (pH 4.0–3.0) with a somewhat higher conductance. Profiles obtained from within the solifluction lobe are composed entirely of the acidic soil, and where soil erosion has, in effect deepened the soil depth by ca. 1 m, soil hydrogen ion concentrations and conductivities can be orders of magnitude greater than in the shallower acidic soil found outside the stream channel. Soil profile data, therefore, further show the influence of solifluction on surface soil chemistry which ultimately affects stream water chemistry, and illustrates the tenuous nature of the upper soil layer which buffers snowmelt from the acidic soil below.

The Stream B basin streamwater chemistry values fall between or below the Gordon Creek and Stream A values, except for total and filtered phosphorus values which are higher (Tables 2, 3 and 4). The Stream B basin surface soil has a somewhat complex pattern of high conductivity and acidity but the patterns of each do not overlap each other, as they do in the other two basins (figure 16). The presence of the ultrabasic intrusion within this catchment compounds the complexity of soil meltwater interactions. The gleysolic cryosols at the outlet of Basin B are quite acidic, and have high exchangeable values for several chemical parameters.

Total and exchangeable chemical analysis gave some surprising results. The underlying grey mineral soils do not appear to be significantly higher in most elements when

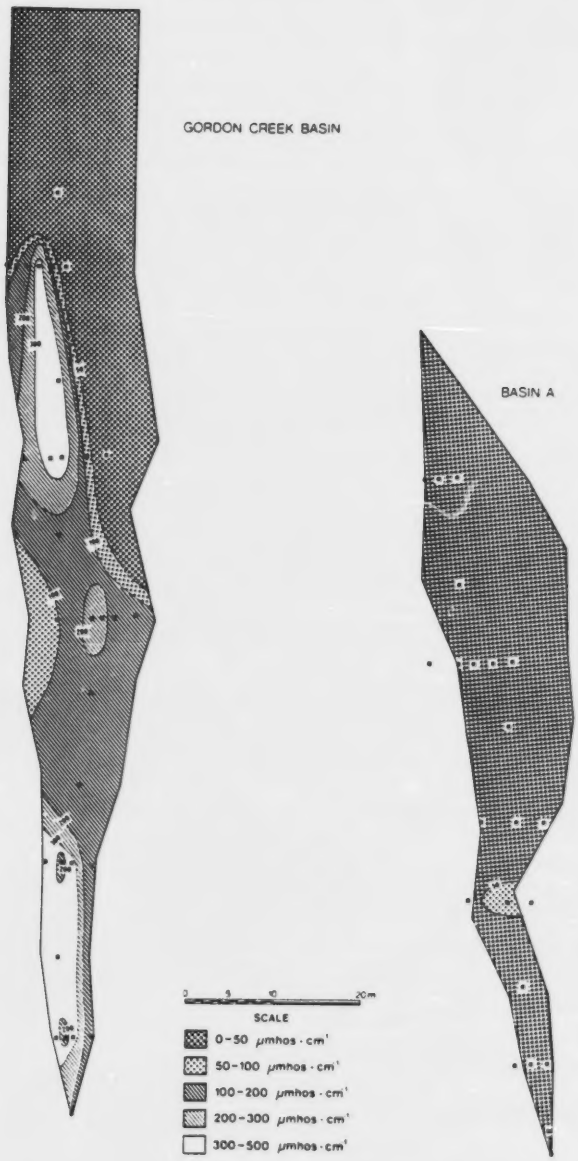


Figure 14. Surface soil (0–5 cm) conductivity 1985.

compared to the overlying brown organic soil, in fact the opposite is true in some cases (Table 8). Iron and sulphate values however do appear to be slightly higher in the underlying grey soils indicating the presence of pyrite. This means that the increased export of material from the acidified basins is largely the result of sulphuric acid-induced chemical weathering rather than differences in elemental concentrations between the two soil types.

Mean streamwater concentrations of TKN and the phosphorus fractions show the opposite of the trend for the other ions (figures 12 and 13), with the undisturbed Basin A showing greater streamwater concentrations of these important biological nutrients. Analysis of phosphorus fractions shows that interbasin variations in total phosphorus results in part from variations in dissolved total phosphorus as well as phosphorus bound to particulate matter as would normally be expected (Johnson and Cole 1977). Finally, even though mean streamwater concentrations of total nitrogen and phosphorus vary between basins by a factor of approximately two, the ratios of these two nutrients are almost identical (ca. 0.13 P:N), indicating a common source for both in all basins.

The losses of these nutrients do not appear to be associated with the soil disturbances in the same manner as was the case with the other ions, and the losses of nutrients from the acidic soil must be lower than from the undisturbed Basin A. The greater losses of these nutrients from Basin A must either occur from this basin's more extensive vegetative cover or its thin upper soil horizon. The results of the soil analyses (Tables 8 and 9) appear to indicate the former. Basin B's

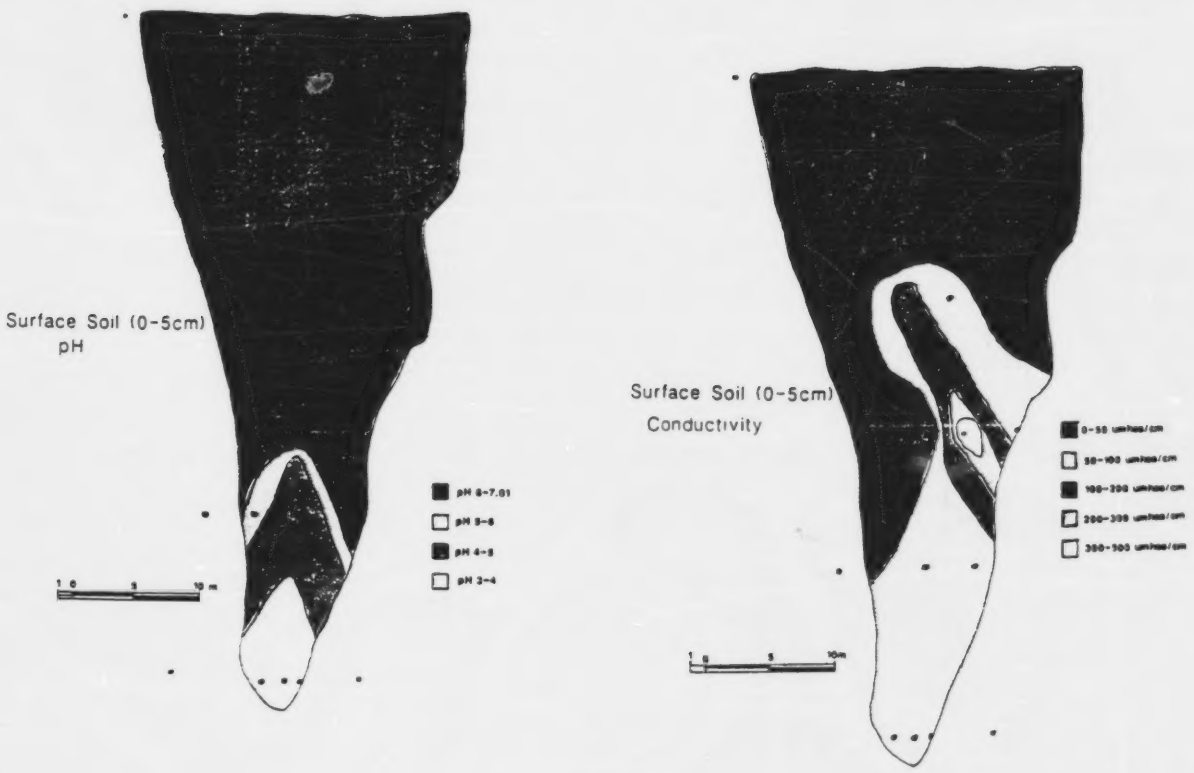


Figure 15 Basin B 1985

high phosphorus values appear to be a combination of higher soil phosphorus values and a relatively high per cent vegetative cover.

The temporal changes in stream chemistry are demonstrated in more detail by the *in situ* stream conductivity measurements (figures 7 and 8). Both streams show essentially the same daily pattern, although the conductivity of Gordon Creek is approximately an order of magnitude greater than Stream A. This indicates that the processes regulating the loss of major ions from each basin are similar, the magnitude of the loss being a function of soil disturbance, as indicated earlier.

Typical daily fluctuations in conductivity begin with a rapid rise in conductivity at the onset of diurnal discharge followed by a similar rapid decline. Often this peak is the maximum conductivity recorded for the day. The magnitude of this daily peak decreases over the period of streamflow until it almost disappears entirely. A rapid rise and fall of conductivity such as this is indicative of the flushing of ion-rich water that remains in contact with soil, from the base of the snowpack, or within the shallow active layer between periods of streamflow. The decline of this peak over time may be a result of a decrease in soil meltwater contact caused by the development of an ice lens at the base of the ablating snowpack. The remainder of the daily conductivity cycle is easier to interpret. Once the initial early peak in conductivity has declined, streamwater conductivity appears to be related to discharge in a simple negative manner. Conductivities declined to minimum values at peak daily discharges and decreased throughout the remainder of the daily cycle.

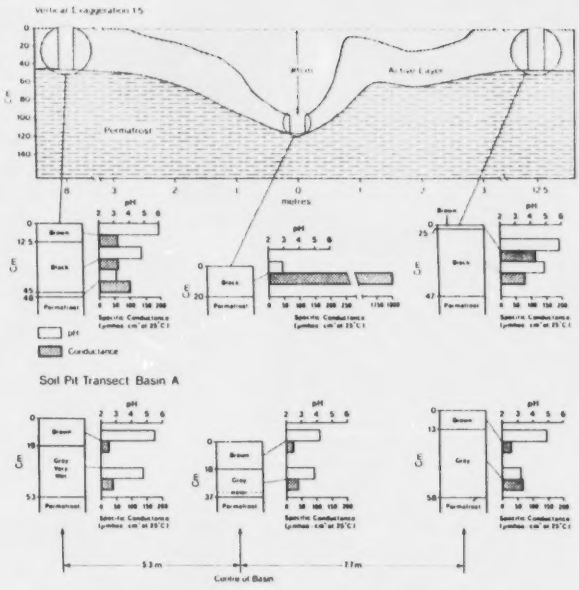


Figure 16. Soil Pit Transect Gordon Greek Basin

Besides drawing attention to interesting patterns which deserve further study, the continuous conductivity data also show the problems involved in obtaining representative samples in streams such as these. When the variability of streamwater chemistry is considered in relation to an equally variable discharge regime, it becomes clear that in order to

gain an accurate estimate of ion export from these basins it is necessary to have frequent, if not continuous, measurements of both discharge and chemistry.

There was no statistically significant difference in per cent vegetative coverage between the study basins (Table 10). This is likely a result of the large within basin variation that occurs as a result of the combining of values of the bare upper block slopes and lower organic terrain. The mean value for per cent coverage is substantially lower for Gordon Creek when compared to Stream A. Basin B's vegetative cover falls somewhere in between the other two basins. There is a significant difference between the number of species found at each sampling site and the frequency of occurrence of several of the plant species. The Gordon Creek basin appears to have a lower species diversity when compared to the other two basins. What is not clear is whether this difference is a result of the actual physical solifluction disturbance, or the exposing of an unsuitable substrate for vegetation recolonization. The presence of *Polytrichum juniperinum* only in the disturbed, acidic sites lends credence to the latter explanation.

Summary

The results from this study give some indication of the complex biogeochemical interactions that occur in the High Arctic. Perturbations of the environment by permafrost processes such as solifluction, can dramatically alter the nutrient and chemical cycling, and eventually the quantity and type of biota, that occupy these ecosystems. Given the long recovery time and fragile nature of permafrost systems, human perturbations should be kept to the minimum and the long term impact of any activity assessed *a priori*.

Acknowledgments

This research was carried out with support from Dept. of Energy, Mines and Resources PCSP, Dept. of Indian and Northern Affairs NSTP, NWT Government, Natural Sciences and Engineering Research Council, Trent University, Ontario Ministry of the Environment, NWRT at Canada Centre for Inland Waters, McGill University and the Dept. of Fisheries and Oceans. The authors would like to thank G. Groulx and B. Stouter for much appreciated technical and analytical assistance.

TABLE 1
Physiographic characteristics of the stream sub-basins studied in the Colour Lake Drainage Basin

BASIN	AREA (ha)	AVERAGE† SLOPE	ASPECT	DURATION OF FLOW 1984	DURATION OF FLOW 1985
Gordon	0.15	19.0°	SE Facing	6 June - 12 June	20 May - 2 June
A	0.08	15.2°	SE Facing	-	21 May - 29 May
B	0.22	22.9°	W Facing	5 June - *	26 May - 20 June
East Inflow	20.2		S Facing	8 June - *	27 May - 11 June Intermittent flow to 1 July
West Inflow	31.9		S Facing	8 June - *	27 May - *

† - Slope Calculated as tan maximum basin relief/basin length
* - Research party left site before stream flow ceased

TABLE 2
Axel Heiberg Gordon Creek chemistry 1985

Date	Time	Discharge (l/sec)	pH	Cond (umho/cm)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Sulphate (mg/L)	Nitrate (mg/L)	Total Unfilt P(mg/L)	Total Filt P(mg/L)	Total Kjeldahl (mg/L)	Sum Cations (Eq/L)	Sum Anions (Eq/L)	Cations-Anions (Eq/L)	Percent Imbalance
20 May	1518	0.132	3.82	686.9	109.40	11.59	0.978	1.327						0.012		6640.6			
21 May	1105	0.016	3.79	662.7	103.40	10.52	0.909	1.500	1.97	0.31	305.60	0.25	0.005	0.016	0.080	6265.4	6434.3	-168.9	- 2.7
21 May	1335	0.007	3.67	710.8	115.39	12.66	0.981	1.260	1.90	0.38	336.20	0.25	0.002	0.005	0.050	7088.4	7073.1	15.3	0.2
26 May	925	0.028	3.83	748.3	110.90	8.30	0.807	1.024	0.50	0.22		0.25	0.024	0.006	0.100	6426.1			
26 May	1215	0.105	3.92	519.2	70.43	5.09	0.565	0.703	0.50	0.05	188.20	0.25	0.012	0.004	0.060	4096.1	3935.0	161.1	3.9
26 May	1515	0.138	4.06	461.2	56.19	6.38	0.626	0.837	0.50	0.05	166.10	0.25	0.059	0.005	0.240	3464.6	3474.8	- 10.2	- 0.3
26 May	2154	0.043	4.04	552.1	68.18	8.88	0.753	0.960	0.50	0.16	209.70	0.25	0.016	0.003	0.110	4281.4	4388.4	-106.9	- 2.5
27 May	745		3.88	469.3	58.44	5.36	0.614	0.718	0.50	0.05	167.80	0.25	0.006	0.003	0.070	3534.1	3510.2	23.9	0.7
27 May	1550	0.377	3.96	387.0	45.70	4.96	0.540	0.720	0.50	0.05	132.10	0.25	0.005	0.010	0.080	2840.1	2767.0	73.2	2.6
28 May	925	0.093	4.03	323.6	38.21	3.13	0.452	0.564	0.50	0.05	105.30	0.25	0.014	0.007	0.080	2291.7	2209.0	82.6	3.6
28 May	1540	0.165	4.04	356.7	40.45	4.20	0.499	0.634	0.50	0.05	117.60	0.25	0.006	0.006	0.060	2493.2	2465.1	28.1	1.1
29 May	1010	0.125	4.08	285.5	39.71	3.53	0.406	0.481	0.50	0.05		0.25	0.013	0.002	0.080	2385.2			
29 May	1533	0.131	4.04	337.3	32.21	2.60	0.457	0.537	0.50	0.05		0.25	0.005	0.005	0.050	1946.0			
30 May	1250		4.18	455.6	34.46	3.00	0.436	0.511	0.50	0.05	100.20	0.25	0.010	0.003		2064.5	2102.8	- 38.3	- 1.9
1 Jun	1030		4.13	280.2	28.46	2.82	0.386	0.487	0.50	0.05	85.6	0.25	0.022	0.006	0.120	1755.6	1798.9	- 43.3	- 2.5
2 Jun	1615	0.028	4.02	411.9	49.45	4.51	0.549	0.632	0.50	0.05	140.10	0.25	0.018	0.001	0.090	2974.2	2933.5	40.7	1.4
Mean				478.0	62.56	6.10	0.622	0.806	0.69	0.11	171.21	0.25	0.014	0.006	0.091	3784.2	3591.0	4.8	0.3
Standard Deviation				155.0	30.63	3.29	0.202	0.321	0.51	0.11	79.30	0.00	0.014	0.004	0.048	1836.2	1670.6	87.7	2.3
Maximum Value				748.3	115.39	12.66	0.981	1.500	1.97	0	336	0	0.059	0.016	0.240	7088.4	7073.1	161.1	3.9
Minimum Value				280.2	28.46	2.60	0.386	0.481	0.50	0.05	85.60	0.25	0.002	0.001	0.050	1755.6	1798.9	-168.9	- 2.7
Number				16	16	16	16	16	15	15	12	15	15	16	14	16	12	12	12

TABLE 3
Axel Heiberg Stream A chemistry 1985

Date	Time	Discharge (l/sec)	pH	Cond (umho/cm)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Sulphate (mg/L)	Nitrate (mg/L)	Total Unfilt P(mg/L)	Total Filt P(mg/L)	Total Kjeldahl (mg/L)	Sum Cations (Eq/L)	Sum Anions (Eq/L)	Cations-Anions (Eq/L)	Percent Imbalance
21 May	1325	0.0240	5.70	64.7	7.15	1.77	0.359	0.703	0.73	0.02	20.10	0.025	0.024	0.018	0.210	538.0	440.1	97.9	18.2
21 May	1930	0.0200	5.70	59.4	6.36	1.66	0.331	0.614	0.75	0.07	18.00	0.025	0.016	0.009	0.170	486.1	399.6	86.5	17.8
23 May	1440	0.0110	5.87	51.4	5.22	1.40	0.331	0.649	0.58	0.14	16.90	0.025	0.076	0.010	0.360	408.0	375.6	32.4	8.0
23 May	1920	0.0290	5.64	54.8	5.56	1.46	0.322	0.609	0.38	0.02	17.60	0.025	0.021	0.009	0.150	429.5	378.2	51.3	11.9
23 May	2145	0.0086	5.87	59.5	6.70	1.67	0.364	0.646	0.54	0.07	21.70	0.025	0.014	0.010	0.130	505.5	470.7	34.8	6.9
24 May	1010	0.0430	5.62	50.0	5.11	1.34	0.317	0.661	0.46	0.13	16.10	0.025	0.082	0.021	0.330	398.3	355.0	43.3	10.9
24 May	1650	0.0720	5.76	52.7	4.77	1.27	0.296	0.611	0.46	0.07	16.30	0.025	0.032	0.018	0.210	372.8	356.0	16.8	4.5
24 May	2110	0.0170	5.43	64.5	7.04	1.81	0.355	0.669	0.53	0.13	23.10	0.025	0.020	0.011	0.140	536.5	502.7	33.8	6.3
25 May	1030	0.0420	5.52	54.1	5.33	1.37	0.315	0.609	0.39	0.02	16.50	0.025	0.046	0.016	0.230	411.0	355.6	55.4	13.5
25 May	1920	0.0520	5.67	58.8	6.24	1.58	0.340	0.633	0.45	0.12	19.60	0.025	0.017	0.009	0.140	474.5	427.1	47.4	10.0
25 May	2205	0.0200	5.59	77.6									0.015	0.010					
26 May	900	0.1130	5.71	63.5	6.02	1.51	0.326	0.664	0.43	0.12	17.80	0.025	0.030	0.013	0.210	457.8	389.0	68.7	15.0
27 May	1620	0.0780	5.96	62.6	5.56	1.38	0.315	0.669	0.44	0.06	16.00	0.025	0.011	0.011	0.160	422.9	348.7	74.2	17.6
28 May	945	0.0240	5.55	84.4	7.49	1.84	0.404	0.768	0.47	0.15	23.40	0.025	0.029	0.012	0.200	565.2	508.3	56.9	10.1
28 May	2150		5.42	80.6	7.38	1.82	0.568	0.681	0.46	0.10	23.30	0.025	0.008	0.008	0.280	564.0	503.3	60.6	10.7
29 May	1604	0.0701	6.27	68.0	5.68	1.49	0.538	0.712	0.29	0.13	17.60	0.025	0.012	0.010	0.130	448.2	381.4	66.7	14.9
Mean				62.9	6.11	1.56	0.365	0.660	0.491	0.090	18.93	0.025	0.028	0.012	0.203	467.9	412.8	55.1	11.7
Standard Deviation				10.4	0.88	0.19	0.081	0.044	0.123	0.046	2.74	0.000	0.022	0.004	0.072	62.6	58.5	21.7	4.3
Maximum Value				84.4	7.49	1.84	0.568	0.768	0.750	0.150	23.40	0.025	0.082	0.021	0.360	565.2	508.3	97.9	18.2
Minimum Value				50.0	4.77	1.27	0.296	0.609	0.290	0.020	16.00	0.025	0.008	0.008	0.130	372.8	348.7	16.8	4.5
Number				16	15	15	15	15	15	15	15	15	16	16	15	15	15	15	15

TABLE 4
Axel Heiberg Stream B chemistry 1985

Date	Time	pH	Cond (umho/cm)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Sulphate (mg/L)	Nitrate (mg/L)	Total Unfilt P(mg/L)	Total Filt P(mg/L)	Total Kjeldahl (mg/L)	Sum Cations (Eq/L)	Sum Anions (Eq/L)	Cations-Anions (Eq/L)	Percent Imbalance
26 May	1700			35.54	0.337	0.315	0.296	0.05	0.10	78.50	0.25	0.010	0.007	0.090	1892.5	1641.0	181.5	10.0
27 May	1212	5.23	247.2	34.40	0.314	0.279	0.324	1.72	0.10	80.00	0.25	0.013	0.003	0.120	1768.7	1719.3	49.4	2.8
27 May	2206	5.82	347.5	27.36	0.255	0.199	0.206	0.05	0.10	60.60	0.25	0.043	0.005	0.070	1401.7	1268.3	133.4	9.5
28 May	438	5.59	250.1	35.99	0.322	0.271	0.239	0.5	0.05	84.40	0.25		0.006		1842.9	1773.9	69.0	3.7
28 May	930	6.06	301.7	39.17	0.374	0.388	0.280	1.68	0.10	100.90	0.25	0.010	0.003	0.090	2010.3	2153.3	-143.1	- 7.1
28 May	1438			54.05	0.568	0.470	0.362	1.72	0.10	128.80	0.25	0.012	0.005	0.120	2773.5	2735.3	38.2	1.4
28 May	2126	5.68	191.9	26.79	0.255	0.199	0.198	0.5	0.10	58.90	0.25	0.005	0.003	0.050	1373.6	1245.6	128.0	9.3
29 May	423	5.90	274.7	40.53	0.352	0.290	0.226	0.5	0.10	91.00	0.25	0.005	0.005	0.070	2071.1	1913.9	157.1	7.6
29 May	1035	5.80	363.9	44.73	0.404	0.337	0.282	0.5	0.10	128.10	0.25	0.007		0.080	2288.7	2686.3	-397.6	-17.4
29 May	1207	5.81	383.7	55.29	0.501	0.440	0.290	1.72	0.10	137.80	0.25	0.010	0.007	0.100	2828.3	2922.7	- 94.4	- 3.3
29 May	1453	5.65	391.3	60.40	0.568	0.504	0.327	0.5	0.10	139.80	0.25	0.010	0.006	0.090	3093.2	2929.9	163.3	5.3
1 Jun	2139	6.08	118.2	15.55	0.197	0.168	0.185	0.39	0.10	35.40	0.25		0.002		805.0	753.3	51.8	6.4
2 Jun	1546	5.70		14.19	0.178	0.274	0.208	0.38	0.10	32.90	0.25		0.003		740.0	700.9	39.0	5.3
3 Jun	1508	6.24	96.9	12.49	0.156	0.137	0.161	0.5	0.10	27.50	0.25	0.016		0.120	646.7	591.9	54.8	8.5
6 Jun	2306	5.29	135.2	18.17	0.206	0.213	0.204	0.5	0.10	40.40	0.25	0.005	0.005	0.130	943.2	860.5	82.8	8.8
13 Jun	1408	5.25	193.6	28.16	0.329	0.357	0.226	0.5	0.10	66.40	0.25	0.000	0.007	0.130	1459.2	1401.8	57.4	3.9
20 Jun	1400			34.63	0.434	0.447	0.206	0.5	0.10	81.00	0.25	0.000		0.170	1788.5	1705.7	82.7	4.6
Mean			253.5	33.97	0.338	0.311	0.248	0.72	0.10	80.73	0.25	0.010	0.005	0.102	1744.5	1706.1	38.4	3.5
Standard Dev			101.6	14.87	0.131	0.114	0.058	0.578	0.013	38.050	0.000	0.011	0.002	0.033	757.8	800.7	139.5	7.1
Maximum Value			391.3	60.40	0.568	0.504	0.362	1.72	0.10	139.80	0.25	0.043	0.007	0.170	3093.2	2929.9	181.5	10.0
Minimum Value			96.9	12.49	0.156	0.137	0.161	0.05	0.05	27.50	0.25	0.000	0.002	0.050	646.7	591.9	-397.6	-17.4
Number			13	17	17	17	17	17	17	17	17	14	14	14	17	17	17	17

TABLE 5
Permafrost depth Gordon Creek Basin 1985

Site	Frost Depth cm 20 May	Frost Depth cm 21 May	Frost Depth cm 24 May	Frost Depth cm 26 May	Frost Depth cm 28 May	Frost Depth cm 29 May	Frost Depth cm 8 June
1	0	0	0	0	0	0	15
2	16	19.5	25	32	38	38	52
3	17	19	25	27	33	45.5	61
4	8	12	16.5	20	24	24	45
5	0	0	0	1	27	33.5	43
6	0	0	0	0	11	0	40
7	0	0	0	0	0	0	25
8	0	0	0	0	0	0	27
9	0	0	0	0	0	0	15
10	0	0	0	0	0	0	12
11	0	0	0	4	0	4.5	26
12	20	19.5	46.2	35	--	--	--
13	18	20	42.5	30	--	--	--
14	20	20	--	25	--	--	--

TABLE 6
Permafrost depth Basin A 1985

Site	Frost Depth cm 22 May	Frost Depth cm 24 May	Frost Depth cm 25 May	Frost Depth cm 26 May	Frost Depth cm 29 May	Frost Depth cm 8 June
1	0	0	0	0	16	+5
2	15	20.5	27	37	+8	52
3	3	22	29	25	25	35
4	19	122	27	25	+4	52
5	0	0	0	0	--	--
6	0	0	0	2.5	--	--
7	0	0	0	0	--	--
8	0	0	0	0	--	--
9	20	30.5	23	25	--	--
10	16	23	24	24	--	--
11	0	0	0	0	--	--

TABLE 7
Permafrost depth Basin B 1985

Site	Frost Depth cm 19 May	Frost Depth cm 22 May	Frost Depth cm 26 May	Frost Depth cm 28 May	Frost Depth cm 8 June
B 1	0	0	0	4.5	29
B 2	0	0	0	0	37
B 3	0	0	0	0	19
B 4	0	0	0	0	0
B 5	0	0	0	0	0
B 6	2	2	0	19	0
B 7	0	0	0	0	0
B 8	0	0	0	0	30
B 9	2	21	26	31	39
B10	9	16	32.5	47	55

TABLE 8
Summary of soil total chemical analyses (% Dry Weight)

Static Cryosols

Thin Arctic Brown Soil Types

	N	P	S	K	Mg	Fe	Mn	Al	Na
Basin A, N=4	.12±.04	.03±.01	.03±.01	.1±.1	.4±.2	.3±.1	.03±.01	5.6±.5	.46±.1
Gordon Creek, N=3	.13±.03	.03±.01	1.4±.3	.2±.1	.4±.2	.4±.1	.02±.01	5.4±.4	.43±.1
Basin B, N=1	.14	.07	.03	.4	.62	4.96	.034	4.49	2.04

Gray Silt-loam Soil Types

Basin A, N=3	.11±.03	.04±.01	.04±.01	1.1±.2	.1±.1	.1±.1	.03±.01	.05±.02	4.08±.17	.01±.01	.03±.01	5.64±.14	0.27±.1	.02±.01
Gordon Creek, N=3	.14±.03	.03±.01	.03±.01	1.4±.1	.1±.1	.2±.1	.03±.01	.04±.01	4.11±.14	.03±.01	.03±.01	5.43±.14	0.31±.2	.02±.01

Turbic Cryosols[A]

Light coloured, sandy with gypsum, N=1	.10	.04	.03	.44	.063	6.02	.080	4.43	2.25
Gray coloured, sandy with gypsum, N=1	.041	.071	.045	1.47	.032	5.44	.004	3.43	2.21
Red coloured, rocky gypsum, absent, N=1	.10	.07	.08	1.22	.063	5.44	.008	5.61	3.25
Gleyed, mottled gray-brown coloured, gypsum absent, N=2	.11±.14	.04±.04	1.4±1	.1±	.15±.04	.1±.1	4.68±.15	.03±.01	.01±.01	5.66±1.01	1.69±.01

[A]All samples from Basin B.
[AA]First value $\bar{x}$, 2nd value s.d.

TABLE 9
Summary of soil exchangeable and organic content anayses

Static Cryosols

Thin Arctic Brown Soil Types

	P µg/g	K %	Mg %	Ca %	Fe µg/g	Mn µg/g	Al µg/g	Na µg/g	S %	CEC meq/100g	O.M. %
Basin A, N=4	.1±5	1.1±.1	.01±.002	.02±.01	.1±6.1	1.1±.1	11.6±2.1	46.6±9.1	.1±1	1.4±.2	.002±.001	1.05±.1	1.2±.2	1.2±.1
Gordon Creek, N=3	3.1±.4	2.4±.1	.007±.001	.007±.005	.004±.01	4.6±.5	10.2±.9	11.6±.9	14.0±.1	1.5±.1	4.0±.1	.003±.001	1.6±.5	3.2±.1	3.4±.1	1.1±.1
Basin B, N=1	.7±0	.002	.006	.77	.020	11.62	.05	21.64	.012	8.503	1.1±

Gray Silt-loam Soil Types

Basin A, N=3	1.0±.1	.4±0	.01±.001	.01±.002	.04±.1	.07±.05	1.2±.1	.1±0	4.2±.1	2.6±1	7.1±.1	41.0±.1	1.2±.1	7.1±.1	.2±0	.1±0	11.4±.1	2.6±0	4.2±.1	.2±.1
Gordon Creek, N=3	0.5±.1	0.6±.1	.006±.002	.002±.001	.006±.004	.05±.03	.7±.1	2.0±1	3.5±1	1.2±.1	.2±.1	2.4±.5	10.7±1	4.4±.1	1.1±.1	.1±.1	2.0±.1	.1±0	3.1±.1	.2±.1

Turbic Cryosols[A]

Light coloured, sandy
with gypsum, N=1 .960 .001 .002 .613 .300 9.28 0.00 17.51 .436 7.64 1.04

Gray coloured, sandy
with gypsum, N=1 .250 .001 .001 1.7.4 1.14 .760 0.00 14.64 11.84 5.47 .961

Red coloured, rocky
gypsum absent, N=1 .820 .001 .001 .7e4 .650 2.200 21.44 27.45 .142 4.74 .584

Gleyed, mottled gray-
brown coloured, gypsum
absent, N=2 1.00 .148 .005 .0007 .002 .0001 .1±1 .045 12.71 25.1 41.04 25.17 45.58 31.56 12.62 1.41 .162 .023 4.15 .1±4 2.4± .36±

[A]All samples from Basin B.
[AA]First values $\bar{x}$, 2nd values s.d.

TABLE 10
1985, Gordon Creek, Basin B and Basin A vegetation summary

	Gordon Creek		Basin B		Basin A	
Saxifraga tricuspidata	3		1		1	
Kobresia myorsuroides	8		3		5	
Polyfrichum juniperinuus	13		11		14	
Cladonia cornuta	9		18		19	
Unidentified moss	1				2	
Dryas integrifolia	1		6		14	
Unidentified lichen	1		1		5	
Harsupellia sp	1					
Pontentilla pulchella					1	
Papaver radiatum	4					
Silene aculis			1			
Rhocomitrium hnuginosum	5		7		11	
Cassiope tetragona	1		6		9	
Salix arctica	6		11		19	
Cefraria nivalis	1		8		14	
Polygonum viviparum	2				9	
Saxifraga oppositifolia	2		5		6	
Carex nardina	8		8		10	
Unidentified vascular plant	1					
N	19		20		20	
Total species	17		13		15	
Number of species at each site	3.9	3.7	6.6	4.9	8.6	5.8
Per cent coverage	39.0	39.8	61.0	40.6	66.7	33.1
	x̄	sd	x̄	sd	x̄	sd

References

Allan, C.J., 1986. Some observations of the role of snow and ice on the chemistry of a high arctic lake. Proc. East. Snow Conf. 43. (in press).

Allan, C.J., S. Schiff, D. Pierson, M. English, M. Ecclestone and W.P. Adams. Meltwater mixing processes in a naturally acidified high arctic lake. Presented 1985 Fall Meet. Amer. Geophysical Union, San Fran., Abstract in EOS, 66(46):896.

Allan, C.J., S. Schiff, D. Pierson, M. English, M. Ecclestone and W.P. Adams. Limnologic data from Colour Lake, Axel Heiberg Island, N.W.T. McGill University Subarctic and Axel Heiberg Data Report. (in prep).

Black, C.A., D.D. Evans, J.L. White, L.E. Ensminger, F.E. Clark and R.C. Dinauer. 1965. Methods of Soil Analysis, Vol. 2, Amer. Soc. of Agronomy Inc., Madison, Wisc. 801 p.

Blatter, H. 1985. On the thermal regime of arctic glaciers, A study of the White Glacier, Axel Heiberg Island and the Laika Glacier, Coborg Island, Canadian Arctic Archipelago. Zurich Geographishe, Schrften 22, pp. 35-40.

Briggs, D. 1981. Sources and Methods in Geography, Soils. Butterworths, Toronto. 192 p.

Canada Soil Survey Committee on Soil Classification. 1978. The Canadian system of soil classification. Can. Dep. Agric. Publ. 1646, Supply and Services Canada, Ottawa, Ont. 164 pp.

Drever, J.I. 1982. The Geochemistry of Natural Waters. Prentice-Hall, Englewood Cliffs, N.J. 388 p.

Fricker, P.E. 1963a. Geologic work in the expedition area. AHIRR Preliminary Reports 1961-1962. pp. 127-132.

Fricker, P.E. 1963b. Geology of the expedition area. AHIRR. Geology No. 1, 156 p.

Johnson, D.W. and D.W. Cole. 1977. Anion mobility in soils: Relevance to nutrient transfer from terrestrial to aquatic ecosystems, U.S. EPA Rept. EPA 6001 3-77-068, U.S. Govt. Print. Offc., Wash. D.C.

Kranck, E.H. 1963. Tectonics of the evaporite diapirs on Axel Heiberg Island. AHIRR Preliminary Reports 1961-1962. pp. 133-138.

Likens, G.E., F.H. Bormann, R.S. Pierce, J.S. Eaton and N.M. Johnson. 1977. Biogeochemistry of a Forested Ecosystem. Springer-Verlag, New York, 147 p.

Muller, F. (ed.) 1963. Preliminary Reports 1961-1962. AHIRR. 241 p.

Muller, F. and N. Roskin-Sharling. 1967. A high arctic climatic study on Axel Heiberg Island, Canadian Arctic Archipelago-summer 1961 general meteorology. AHIRR Meterology No. 3. 82 p.

Ohmura, A. 1981. Climate and energy balance on arctic tundra, Axel Heiberg Island spring and summer 1969, 1970, 1972. Zurich Geographishe Scotten, Zurich.

Peech, M. 1965. Hydrogen ion activity, In Methods of Soil Analysis C.A. Black et al. eds., V. 2. American Society of Agronomy Inc., Madison, Wisc.

Pierson, D., S. Schiff, M. English, M. Ecclestone, C. Allan and W.P. Adams. 1985. Spatial variations in the chemistry of small permafrost basins including the influence of solifluction. Presented at the 1985 Fall Meeting Amer. Geophys. Union, San Fran., Abstract in EOS 66(46):896.

Polunin, N. 1959. Circumpolar Arctic Flora. Clarendon Press, Oxford, 514 p.

Porsild, A.E. 1964. Illustrated Flora of the Canadian Arctic Archipelago. Queen's Printer, Ottawa, 218 p.

Small, H., T.S. Stevens and W.C. Bauman. 1975. Novel ion exchange chromatography method using condumetric detection. Anal. Chem. (47)11: 1801-1804.

Stainton, M.P., P.J. Capel and F.A.J. Armstrong. 1977. The chemical analysis of freshwater. Fish. Mar. Serv. Misc. Spec. Publ. 25, 119 p.

Tedrow, J.C.F. 1977. Soils of the Polar Landscapes. Rutgers University Press, New Brunswick, N.J. 638.

Woo, M.K. 1982. Snow hydrology of the high arctic. Proc. West. Snow Conf., 63-73.

FURTHER EVIDENCE OF HERMAPHRODITISM IN *LEPIDURUS ARCTICUS* (CRUSTACEA, NOTOSTRACA) FROM THE MELVILLE PENINSULA AREA, N.W.T.

Margaret J. Beaton and P.D.N. Hebert

Department of Biology, University of Windsor, Windsor, Ontario N9B 3P4

Level: M. Beaton, Master's

Abstract

Populations of the arctic notostracan crustacean, *Lepidurus arcticus*, typically show severely skewed sex ratios with females outnumbering males by a ratio of 100:1. The breeding strategy employed by this species has been a topic of controversy. The lack of males has been attributed to either asexual reproduction or to hermaphroditism. To resolve this controversy, three sites in close proximity were studied in the Baffin region of the N.W.T. during 17 July to 15 August 1986; Igloolik Island (10 populations), Avajaaq (Coxe Islands) (3 populations), and Sarcpa Lake (1 population). Enzyme electrophoresis was used to determine and compare the extent of frequency differences at allozyme loci within and between populations. Fifteen enzyme loci were examined for all populations. An additional 10 enzyme loci were examined for some of the populations. The survey indicated that polymorphism is extremely rare. These results suggest that the species is a self-fertilizing hermaphrodite, and that the area under study has been colonized by a single lineage.

In addition to the genetics study, samples from four of the Igloolik Island populations were collected at regular intervals to study growth rates and determine sex ratios. The incidence of males at Igloolik appears to be considerably higher than found previously on Baffin Island.

These results will be discussed in terms of breeding strategies employed by arctic zooplankton.

Key words: Population genetics, Igloolik, hermaphrodites, notostraca.

Résumé

Les populations de crustacés notostracés de l'Arctique: *Lepidurus arcticus*, montrent en général une proportion mâles/femelles fortement dissymétrique, soit 1/100. La stratégie de reproduction adoptée par cette espèce de lepidurus a causé quelques controverses. Certains ont attribué la rareté des mâles à une reproduction parthénogénétique, ou à un hermaphrodisme des individus. Pour résoudre la controverse, les auteurs ont observé les *L. arcticus* du 17 juillet au 15 août 1986 dans trois sites proches l'un de l'autre dans la région de Baffin des T.N.-O.: à l'île Igloolik (10 populations), à Avajaak (îles de Coxe) (3 populations) et au lac Sarcpa (1 population). Ils ont utilisé la méthode d'électrophorèse des enzymes pour évaluer et comparer l'ampleur des différences de fréquence aux sites allozymatiques tant au sein d'une population qu'entre plusieurs. Ils ont examiné 15 localisations d'enzymes dans toutes les populations et 10 autres localisations pour certaines d'entre elles. Cet examen a mis en relief l'extrême rareté du polymorphisme du lepidurus et indique que c'est un hermaphrodite autofécondateur, et que les sites étudiés ont été colonisés par une seule lignée.

Outre cette étude génétique, les auteurs ont échantillonné, à intervalles réguliers, quatre populations de l'île Igloolik en vue d'étudier leur taux de croissance et la proportion mâles/femelles. La proportion des mâles à l'île Igloolik paraît beaucoup plus élevée que celle relevée précédemment à l'île de Baffin.

Ces conclusions seront examinées dans l'optique des stratégies de reproduction utilisées par le zooplankton de l'Arctique.

Mots-clés: génétique des populations, Igloolik, hermaphrodite, notostracé.

Introduction

The use of electrophoresis has provided extensive information on the levels of genetic variation in natural populations of both plants and animals. Analysis of these data has uncovered a number of trends in the levels of intra and interpopulation variation (Powell, 1975; Nevo, 1978; Hamrick *et al.*, 1979; Loveless and Hamrick, 1984). First, invertebrates generally show more genetic variability (measured as either % polymorphic loci or average heterozygosity per locus) than plants, which are themselves more variable than vertebrates (Powell, 1975; Nevo, 1978). On average, natural populations of invertebrates possess allozyme variation at approximately 40% of their loci, and individuals are heterozygous at 11% of their loci (Nevo, 1978). Levels of variation are affected by shifts in the breeding system. Species which regularly engage in self-fertilization have less intrapopulation variation than those reproducing through outcrossing (Nevo, 1978; Hamrick *et al.*, 1979). This is what might be expected, since strict inbreeders are unable to recombine their genes resulting in a number of lines homozygous at most loci (Nei, 1975). Electrophoretic studies have shown, however, that asexual species are as genetically variable as sexual species (Nei, 1975; Powell, 1975). The groups which may nonetheless be distinguished as genotypic frequencies in asexual populations, are generally not in Hardy-Weinberg equilibrium and there are usually fewer genotypes per population than in sexual populations. In old asexual lineages, one expects individuals to be heterozygous at many loci as a result of mutation (Nei, 1975) and this expectation has often been confirmed (for a review see Nevo, 1978). Thus sufficient differences in patterns of genetic variation exist to employ electrophoretic analysis as a diagnostic tool in the determination of breeding systems.

The arctic tadpole shrimp, *Lepidurus arcticus* (Pallus), has an Holarctic distribution. In North America, the species is most common north of the arctic circle (66°N) and has only

been collected at two sites south of 60°N (Johansen, 1922; Reed, 1963; Bushnell and Byron, 1979; Havas and Hutchinson, 1982; Hebert and Hann, 1986). Most of the past work involving *L. arcticus* has been in the fields of morphological taxonomy and geographical distribution and there remains uncertainty concerning its breeding strategy. In a study of the taxonomy and morphology of notostracans, Linder (1952) studied populations of *L. arcticus* from 3 sites in Alaska and N.W.T. As only one male was present among 147 individuals, Linder concluded that the species reproduced parthenogenetically. However, Longhurst (1954), in a study of notostracan reproduction reported the frequent presence of ovotestes in species lacking males, including females of *L. arcticus* from Alaska. He suggested that females in such populations engaged in self-fertilization but that the rare males might permit a limited amount of outcrossing (Longhurst, 1955). Although most researchers (Bell, 1982) have accepted Longhurst's conclusion, no subsequent work on the breeding strategy of the species has been reported.

The present study aimed to elucidate the breeding structure of the species by employing electrophoresis to characterize isozyme differences within and between populations of *L. arcticus*. As already indicated, patterns of genetic variation should indicate the breeding strategy used by the species.

Materials and methods

L. arcticus was sampled at three sites in the Melville Peninsula area, N.W.T. (Fig. 1). The most extensive collections were made on the island of Igloolik (69° 22′N, 81° 48′W) The remaining sites were Avajaaq, approximately 6 km west (69° 22′N, 81° 48′W), and Sarcpa Lake area, 112 km south of Igloolik (68° 34′N, 83° 15′W). These sites will hereafter be referred to with the codes Ig, Av, and Sa respectively.

Sampling was performed in the ponds between 26 July and 15 August, 1986 using fine mesh fish nets. Collections were made by wading through the habitats and netting animals as they swam along or while buried in the mucky bottom. In ponds which were too deep to see the bottom, the sediments were gently stirred, and disturbed animals were captured as they attempted to reorient themselves. Sample sizes varied with weather and pond, however, the goal was 24 animals per pond. For each of the ten Igloolik populations, the approximate date when pond surface became free of ice was noted. Conductivity was measured 3 times per pond at bi-weekly intervals during the period 7 July to 6 August, 1986.

Four populations from Igloolik were resampled at regular intervals to study growth rates and sex ratios. The 4 populations (15, 40, 118, and 135), were sampled on four dates in August (1, 5, 10, and 15). Animals from pond 15 were also collected on 31 August, but an early freeze made it impossible to resample the other three ponds on this date. Animals were fixed in 3:1 methanol:glacial acetic acid for 1 hour, transferred through 95% ethanol (1 hour) and held in 70% ethanol. This allowed later study of the gonadal tissue using Feulgen staining. Measurements performed on individuals included median length of the carapace, length of the supra-anal plate (SAP), presence of brood pouch on the eleventh thoracic appendages, and presence and number of eggs in the brood pouch. Sex determination was based on the presence or absence of the brood pouch. This trait could be scored in pre-reproductive individuals as small as 4.0 mm (median carapace length).

Electrophoresis was carried out following the methods of Hebert and Beaton (1986), with the exception of a modification in sample preparation. It was discovered that proteolytic activity in whole animal extracts caused the degradation of some enzyme systems. In order to minimize this, the carapace and head, which contained most of the proteolytic activity, were removed prior to extract preparation.

Animals were examined for electrophoretic variation of 22 enzymes, representing 30 presumptive loci. Additional enzyme systems were checked (alkaline phosphatase, esterase, leucine amino peptidase (PEP-E), and phenylalanine proline peptidase (PEP-D)) but the activities were too weak to be scored. Ten populations were studied at Igloolik, 3 at Avajaaq, and 1 at Sarcpa Lake. Animals from one reference population were run alongside those from the other populations in order to identify any allelic substitutions which might exist between populations.

All statistics were performed using the Sokal and Rolhf Biometry package on an IBM PC computer.

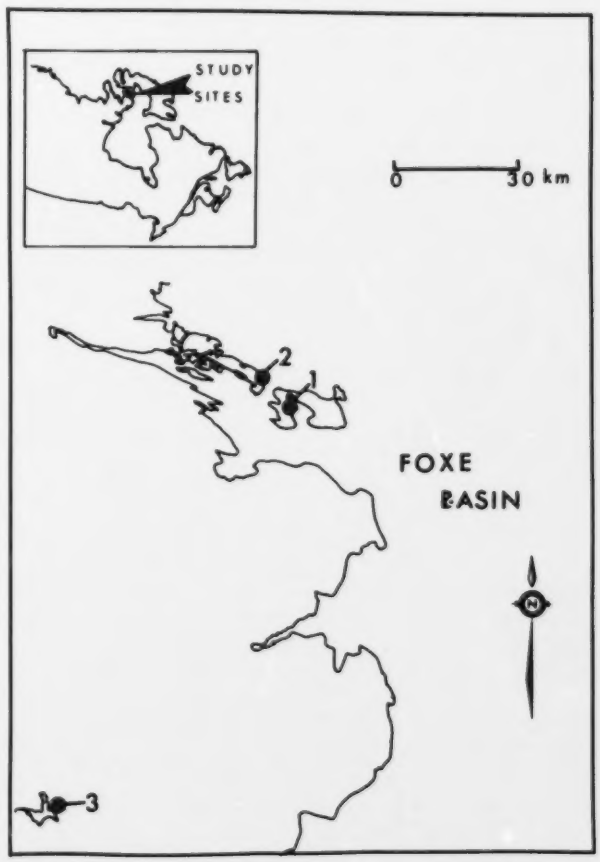


Figure 1. Map of the study area. Location of Igloolik (1), Avajaaq (2), and Sarcpa Lake (3) indicated.

TABLE 1
Physico-chemical data of ponds. Mean conductivity ± standard error. n.a. = data not available, * = growth study ponds.

Pond	Ice out Date (July)	Mean Cond. (uS/m)	# animals
Ig			
15*	5	1543 ± 308	61
31	14	439 ± 83	44
40*	9	347 ± 24	33
47	14	338 ± 58	24
53	14	251 ± 52	24
56	11	354 ± 48	24
73	7	169 ± 117	31
118*	11	405 ± 176	31
123	3	368 ± 99	73
135*	14	239 ± 75	54
Av			
2	n.a.	n.a.	10
4	n.a.	n.a.	27
6	n.a.	n.a.	27
Sa			
3	n.a.	n.a.	22
Total			485

Results

Distributional patterns and body size variation

During the summers of 1985 and 1986, *L. arcticus* was observed in 57 of 174 ponds (32.8%) on Igloolik island. In 1985, the mean conductivity (±std. dev.) for ponds with *L. arcticus* was 331.5 ± 225.7, while the mean for all ponds was 347.6 ± 325.2 uS/cm. A test of difference between means (z = 0.402) indicated that no relationship between conductivity and presence of the species could be discerned. Table 1 shows physico-chemical data and the sample sizes for the populations on which electrophoresis was performed. Casual observation indicated that *L. arcticus* was most common in the habitats with soft mucky sediments as opposed to those with a rocky or sandy bottom.

All four populations showed a rapid increase in mean carapace lengths and mean SAP lengths between 1 August and 20 August, although differences between populations were evident (Fig. 2). There was a 2 week difference in the timing of ice-out for the 4 ponds which were sampled (Table 1). This difference in ice-out time among the ponds appears to account for the difference in initial size of individuals in each pond (r = −0.955).

A typical example of the relationship between carapace and SAP length (Fig. 3) indicates the weakness in using this character to discriminate sexes. Adult males exhibit a more pronounced SAP than adult females, but immature males could not be distinguished from immature females. Attempts to use this character in sexing could result in more biased sex ratios in favour of females. The distribution of carapace lengths for this data was found to be normally distributed at alpha = 0.05 level ($g_1 = 0.133$, $g_2 = -0.285$), but there was a tremendous amount of variation in body sizes.

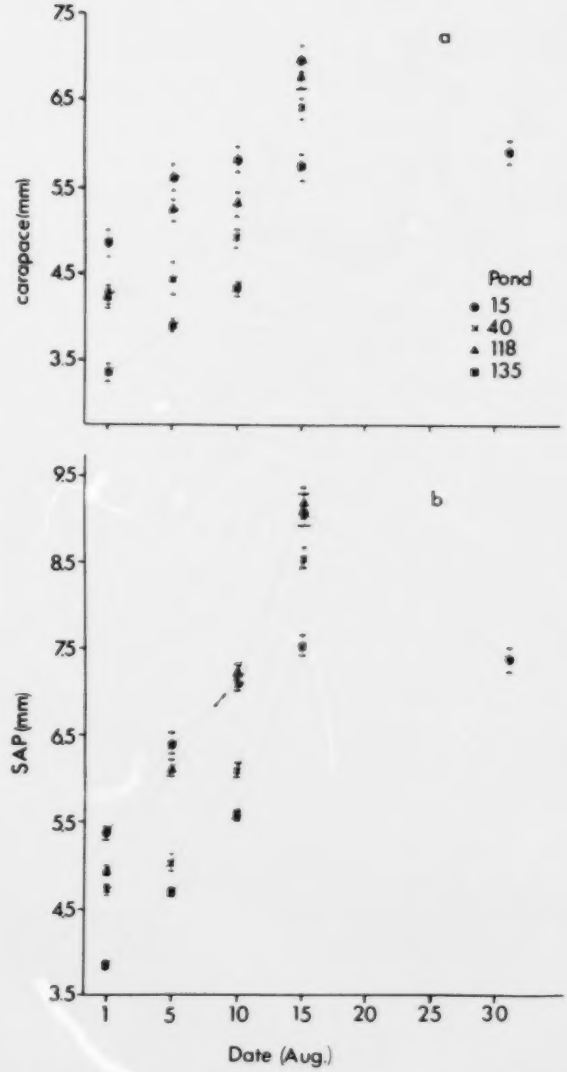


Figure 2. a) Mean carapace length versus sampling date. Bars indicate ±1 standard error.
b) Mean SAP length versus sampling date. Bars indicate ±3 standard errors.

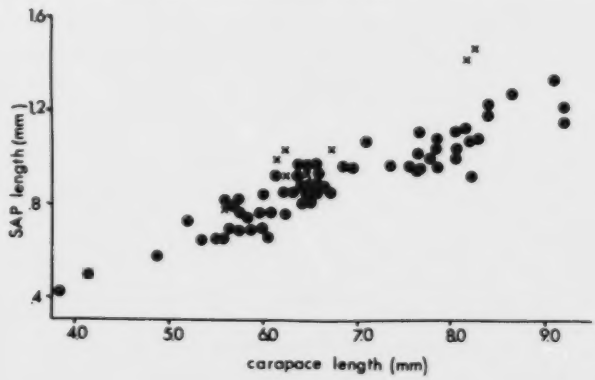


Figure 3. Carapace length versus SAP length for individuals of *L. arcticus* collected from pond 118 on 15 August, 1986. × males, • females.

TABLE 2
Sex ratio data for the four Igloolik ponds on the 5 dates in August, 1986.

Pond	Sex	Date 1	5	10	15	31	Total
15	females	41	58	65	86	40	290
	males	1	0	2	3	4	10
40	females	18	60	76	91		245
	males	0	0	2	4		6
118	females	27	45	67	64		203
	males	3	1	2	8		14
135	females	36	61	68	50		215
	males	0	1	1	1		3

$F_{date} = 2.7155$, $F_{pond} = 3.5178$, $F_{[.05,(3,9)]} = 3.86$

Sex ratios

The sex ratios in each of the 4 Igloolik ponds showed a strong female bias (Table 2). A two-way factorial ANOVA performed on transformed sex ratio data indicated that there were no significant differences among ponds or temporal shifts in the sex ratio (Table 2).

A comparative study of gonad tissue in presumed females versus males is not complete, but a preliminary investigation appears to substantiate previous studies reporting the presence of testes in the posterior section of female gonads (Longhurst, 1954; Longhurst, 1955). The testes appear to make up only a small portion of the entire gonads (10% or less). Furthermore, the appearance of the two tissues is clearly different. Large nurse cells are visible throughout the ovarian tissue, while the testes exhibit a more granular consistency when Feulgen stained.

TABLE 3
Enzyme systems studied, including the number of loci visualized and the number of animals stained for each system.

Enzyme	Abbrev.	# loci	# pops.	# animals
Aconitase	ACON	1	6	69
Adenylate kinase	AK	1	3	12
Aldehyde dehydrogenase	AO	1	13	383
Amylase	AMY	4	13	387
Arginine phosphokinase	APK	1	13	412
Fructose-1,6-diphosphate dehydrogenase	FRUCT	1	7	84
Fumarate hydratase	FUM	1	9	151
Glucose-6-phosphate dehydrogenase	G6PDH	1	5	36
Glutamate oxaloacetate transferase	GOT	1	13	363
Gyceraldehyde-3-phosphate dehydrogenase	G3PDH	1	7	84
Hexokinase	HEX	2	7	204
Isocitrate dehydrogenase	IDH	2	5	36
Lactate dehydrogenase	LDH	1	7	84
Malate dehydrogenase	MDH	1	13	437
Malate dehydrogenase (NADP)	ME	1	13	369
Mannose phosphate isomerase	MPI	1	13	408
Peptidase (leucyl glycine)	PEP(A)	4	9	292
Phosphoglucomutase	PGM	1	14	433
6-Phosphogluconate dehydrogenase	6PGDH	1	12	300
Phosphoglucoseisomerase	PGI	1	14	343
Tetrazolium oxidase	TO	1	5	36
Triose phosphate isomerase	TPI	1	2	21
Total		30		

Allozyme variation

No polymorphic loci were identified among the 30 enzyme loci scored (Table 3). Three of the enzyme systems surveyed for *L. arcticus* (AO, AMY, and PEP(A)) showed interesting staining patterns. AO always stained as two very close bands, and although it was scored as a double-banded single locus, the pattern may actually represent 2 loci. AMY and PEP(A) show patterns similar to one another in that both systems were apparently encoded for by 4 loci, one of which ran cathodally, while three ran anodally. Two other enzyme systems (HEX and IDH) were encoded for by 2 loci of equal staining intensity.

Discussion

The results of the population survey showed that *L. arcticus* was common in ponds at Igloolik. Growth patterns varied among populations apparently as a consequence of variation in ice-out dates for the ponds. Even within a single pond, there was considerable variation in body sizes, perhaps as a result of differential feeding success. Sex ratios in all ponds were strongly female biased, with males comprising an average of 3.4% of the populations. Sex ratios have been previously reported for several Nearctic populations of *L. arcticus* (Johansen, 1922; Linder, 1952; Bushnell and Byron, 1979) with the proportion of males varying from 0% to 30%. This higher percent was based on a small sample (n = 13); further study is necessary to establish geographic patterns in sex ratios if they exist. Examination of the gonadal tissue in females revealed the presence of both ovarian and testicular tissues. The skewed sex ratios and the presence of ovotestes suggest that most if not all females are in fact simultaneous hermaphrodites. Such individuals might reproduce by either self-fertilization or reciprocal outcrossing with other hermaphrodites or males.

The allozyme analysis revealed that populations of *L. arcticus* at the 3 sites in the Melville Peninsula lacked genetic variation at all 30 gene loci. All enzyme phenotypes were apparently homozygous. The absence of variation is atypical of both parthenogens and bisexual species. Moreover, it is incompatible with outcrossing hermaphroditism. Studies on outcrossing hermaphrodites such as the flatworm, *Mesostoma lingua*, have revealed levels of heterozygosity comparable with those in bisexual species (Hebert and Payne, 1985). The role of males in populations of *L. arcticus* cannot be determined until polymorphism is identified. Some amount of outcrossing has been demonstrated in organisms which are primarily inbreeders (Rick and Forbes, 1975; McLeod *et al.*, 1981) and this may prove to be the case in *L. arcticus*.

The results of the present electrophoretic study parallel past studies on inbreeding organisms (Selander and Kaufman, 1973; Rick and Forbes, 1975; Selander and Hudson, 1976; McLeod *et al.*, 1984; Werth *et al.*, 1984). For example, Mediterranean populations of the self-fertilizing hermaphrodite *Rumina decollata* are made up of a number of monogenic or weakly polygenic lines (Selander and Kaufman,

1973; Selander and Hudson, 1976). By contrast, introduced populations in the U.S.A. are invariant, suggesting the area was colonized by a single lineage. Comparison of allozyme patterns in the Mediterranean ancestors suggests that the U.S. lineage originated from Europe, however, the precise locality has not yet been determined.

The absence of variation in populations of *L. arcticus* from the Melville Peninsula mirrors that noted in introduced populations of *R. decollata*. However, population surveys in other areas of arctic North America and Europe are necessary to establish if this lack of variation is a general characteristic of the species. Particular effort should be devoted towards the survey of populations in proximity to glacial refugia, for if variation is present, it should be greatest in these locales. In North America, potential refugia include Beringia and eastern Baffin Island, as well as areas along the southern margin of the species range, which may support populations derived from stocks which survived the Pleistocene along the margin of the continental glaciers (Geological Survey of Canada, 1968). Comparison of genetic diversity in North America and Eurasia populations might provide a likely basis for establishing the evolutionary origins of *L. arcticus*.

In summary, the evidence reported here suggests that *Lepidurus arcticus* is a self-fertilizing hermaphrodite. In addition, the lack of variation among the three Melville Peninsula sites suggests that this area was colonized by a single lineage. Until polymorphic loci are found, the role of males in the populations remains unclear.

Acknowledgments

The research was supported in part by a Natural Sciences and Engineering Research Council of Canada grant to P.D.N.H. M. Beaton acknowledges the support of a DINA Training grant and the logistic support and laboratory space provided by the Eastern Arctic Research Laboratory at Igloolik, N.W.T. Special thanks go to John and Caroline MacDonald for both their support in sampling assistance and their hospitality during our stay. Dr. L. Weider kindly provided the physico-chemical data for the Igloolik ponds. M. Boileau, Dr. D. Innes, D. Stanton, and Dr. L. Weider made helpful comments on the manuscript.

References

Bell, G. 1982. The Masterpiece of Nature. Croom Helm Publ. London.

Bushnell, J.H. and E.R. Byron. 1979. Morphological variability and distribution of aquatic invertebrates (principally Crustacea) from the Cumberland Peninsula and Frobisher Bay regions, Baffin Island, N.W.T., Canada. Arctic and Alpine Research 2:159–177.

Geological Survey of Canada. 1968. The Geologic Map of Canada. No. 1253A.

Hamrick, J.L., Y.B. Linhart, and J.B. Mitton. 1979. Relationships between life history characteristics and electrophoretically detectable genetic variation in plants. Annual Review of Ecology and Systematics 10:173–200.

Havas, M. and T.C. Hutchinson. 1982. Aquatic invertebrates from the Smoking Hills, N.W.T.: effect of pH and metals on mortality. Canadian Journal of Fisheries and Aquatic Sciences 39:890–903.

Hebert, P.D.N. and M.J. Beaton. 1986. Cellulose Acetate Gel Electrophoresis. Department of Biology. University of Windsor, Windsor, Ont. 34 pp.

Hebert, P.D.N. and B.J. Hann. 1986. Patterns in the composition of arctic tundra pond microcrustacean communities. Canadian Journal of Fisheries and Aquatic Sciences 43:1416–1425.

Hebert, P.D.N. and W.J. Payne. 1985. Genetic variation in populations of the hermaphroditic flatworm *Mesostoma lingua* (Turbellaria, Rhabdocoela). Biological Bulletin 169:143–151.

Johansen, F. 1922. Report of the Canadian Arctic Expedition 1913–1918. Vol. VII: Crustacea. Part G; Euphyllopoda. 34 pp.

Linder, F. 1952. Contributions to the morphology and taxonomy of the Branchiopoda Notostraca, with special reference to the North American species. Proceedings of the U.S. National Museum 102:1–69.

Longhurst, A.R. 1954. Reproduction in Notostraca (Crustacea). Nature 173: 781–782.

Longhurst, A.R. 1955. A review of the Notostraca. Bulletin of the British Museum 3:1–57.

Loveless, M.D. and J.L. Hamrick. 1984. Ecological determinants of genetic structure in plant populations. Annual Review of Ecology and Systematics 15:65–95.

McLeod, M.J., D.J. Hornbach, S.I. Guttman, C.M. Way, and A. J. Burky. 1981. Environmental heterogeneity, genetic polymorphism, and reproductive strategies. American Naturalist 118:129–134.

Nei, M. 1975. Molecular Population Genetics and Evolution. American Elsevier Publishing Co., New York. 278 pp.

Nevo, E. 1978. Genetic variation in natural populations: Patterns and theory. Theoretical Population Biology 13:121–177.

Powell, J.R. 1975. Protein variation in natural populations of animals. p. 79–119. In: Dobzhansky, T., M.K. Hecht, and W.C. Steere eds. Evolutionary Biology. v. 8. Plenum Press, New York.

Reed, E.B. 1963. Records of freshwater Crustacea from arctic and subarctic Canada. National Museum of Canada. Bulletin 199. Contributions to Zoology. p. 29–59.

Rick, C.M. and J.F. Forbes. 1975. Allozymes of Galapagos tomatoes: polymorphism, geographic distribution, and affinities. Evolution 29:443–457.

Selander, R.W. and R.O. Hudson. 1976. Animal population breeding structure under close inbreeding: the land snail *Rumina* in southern France. American Naturalist. 110:695–718.

Selander, R.W. and D.W. Kaufman. 1973. Self-fertilization and genetic population structure in a colonizing land snail. Proceedings of the National Academy of Science, U.S.A. 70:1186–1190.

Werth, C.R., J.L. Riopel, and N.W. Gillespie. 1984. Genetic uniformity in an introduced population of witchweed (*Striga asiatica*) in the United States. Weed Science 32:645–648.

NUTRIENT STATUS OF 25- TO 30-YEAR-OLD OPEN FOREST AND TUNDRA WHITE SPRUCE, NEAR CHURCHILL, MANITOBA

Catherine V. Bentley

Faculty of Forestry, University of Toronto, Toronto, Ontario M5S 1A1

Level: Master's

Abstract

White spruce growing in open forest and tundra conditions, at the treeline near Churchill, Manitoba, exhibit different crown forms and growth rates under similar climatic conditions and rooting depths. Nutrient status of foliage and peat were determined for four full-crowned (open forest) and four krummholz (tundra) white spruce, aged 25 to 30. The following variables were significantly higher for the open forest than the tundra: needle weight; needle abundance;

foliar biomass; N, P, Mg and Mn in needles; concentrations of N, P, K, Mg, Na and soluble salts in surrounding peat. The pH of the peat and foliar concentrations of Ca, Fe and Zn were greatest for the tundra. P and K contents were highest in needles produced during a normal year (1985), while other nutrients were highest in foliage of a drought year (1984). Concentrations of P and needle contents of P, K and Mg were higher on the south side of study trees than on the north. The results suggest that nutrient availability may restrict tree growth more on the tundra than in the open forest, and more on the north than on the south side of trees. Compared to the boreal forest, stunted tree growth at the treeline may result from an overall nutrient deficiency.

Key words: Nutrients; white spruce; Churchill, Manitoba; treeline; foliage; peat.

Résumé

Les épinettes blanches qui poussent à la limite nord de la forêt, près de Churchill, Manitoba, portent des houppiers de formes différentes et, avec les mêmes conditions climatiques et profondeurs d'enracinement, leurs rapidités de croissance individuelle sont différentes. L'auteure a évalué la quantité de nutriments disponibles et absorbés par huit épinettes blanches, âgées de 25 à 30 ans. Voici les variables qui sont nettement plus élevées dans la forêt clairsemée que dans la toundra: poids des aiguilles; abondance des aiguilles; poids du feuillage; N, P, Mg et Mn dans les aiguilles, teneurs de la tourbe environnante en N, P, K, Mg, Na, et présence de sels solubles. Le pH de la tourbe et les teneurs des feuilles en Ca, Fe et Zn étaient plus élevées sous l'écotype de toundra. Les teneurs en P et K étaient plus élevées dans les aiguilles ayant poussé en année normale (1985), alors que les autres nutriments étaient plus abondants dans le feuillage d'une année sèche (1984). Les teneurs des aiguilles et les quantités de P, K et Mg contenues étaient plus élevées sur la face sud des arbres étudiés que sur la face nord. L'absorption de nutriments par les épinettes blanches à la limite nord de la forêt indique que leur quantité disponible dans la toundra ralentit la croissance des arbres plus que dans la forêt clairsemée, et sur la face nord plus que sur la face sud. Si on les compare aux arbres et le taïga, ceux de la limite forestière apparaissent rabougris, ce qui pourrait provenir d'une déficience générale de nutriments.

Mots-clés: Nutriments, épinette blanche, Churchill, Manitoba, limite nord de la forêt, feuillage, tourbe.

Introduction

Several processes may limit tree growth at treelines, such as cold temperature and severe prevailing winds (Tranquillini, 1979), shallow depth of snow cover (Hadley and Smith, 1983), low precipitation during growing season (Karlsson, 1985; Scott *et al.*, 1987) and water relations in needles (Goldstein *et al.*, 1985). Different stresses result in variation in treeline crown forms, documented on the east (Payette, 1974) and west coasts of Hudson Bay (Scott *et al.*, 1987) and at altitudinal treelines (Tranquillini, 1979; Kullman, 1986; Yoshino, 1973).

At Churchill, Manitoba, there is less branch elongation on the north, as compared to the south, sides of treeline white spruce (Scott *et al.*, 1987). Full-crowned white spruce dominate the open forest, whereas krummholz forms are characteristic of the tundra (Fig. 1). Open forest trees exhibit greater stem and branch elongation than tundra trees, although the sites can occur within 10 m of each other at the treeline. Less active layer development and the resulting lower ground temperatures occur on tundra compared to open forest (Rouse, 1984; Scott *et al.*, 1987). More snow tends to accumulate in the forest than on the windblown tundra, causing energy to be expended on snowmelt and thereby delaying active layer development in the open forest (Rouse, 1984). Surprisingly, initiation of bud elongation has been recorded in the open forest while there is snow on the ground and the active layer is still frozen (Bentley, 1985).

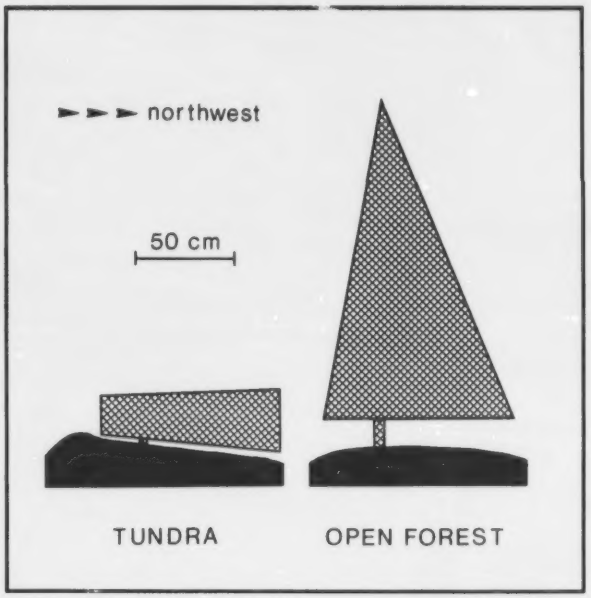


Figure 1. Representative diagram of open forest and tundra study trees, near Churchill, Manitoba; arrows indicate direction of prevailing winds.

The reasons for different crown forms and growth rates in the open forest and tundra are as yet unexplained. Nutrient status may be a factor and is examined here, based on a preliminary study of eight white spruce and surrounding peat. Soil nutrient availability may limit growth in treeline white spruce, and restrict growth of tundra more than open forest trees.

Methods and materials

Sample collection

Eight 25- to 30-year-old white spruce trees were selected for this study, at the treeline near Churchill, Manitoba. These trees were representative of the open forest and tundra sites (Fig. 1).

Both current (1985) and year old (1984) needles were removed from branches in the north, south, east and west quadrants of two whorls in the upper crown. Samples were collected in early autumn, the period when nutrient element levels in foliage are most stable (Leaf, 1973). A total of 64 foliar samples were collected: 2 sites × 2 yrs × 4 trees × 4 directions; one foliar sample (i.e. 1985 needles from north side of one tree) yielded more than 300 needles.

At 1.5 m distant from the base of each tree on the four cardinal directions, peat samples were collected in 10 cm squares, 8 cm in thickness. In total, 32 peat samples were collected: 2 sites × 4 trees × 4 directions.

Laboratory Analysis

Foliage samples were oven dried, ground in a Wiley mill, and digested (Lowther, 1980). Concentrations of K, Ca, Mg, Na, Zn, Mn, Fe, and Cu in the digests were determined by atomic absorption (Grewling, 1976). Phosphorus concentrations were determined by colorimetry, following the molybdenum blue method with stannous chloride as a reducing agent (Allen, 1974). Nitrogen concentrations were determined by the Kjeldahl method (Bremner, 1965).

Peat samples were placed in 200 ml beakers and stirred with distilled water until very moist, and left for 20-24 h, until supersaturated. The pH was measured and the peat extract was obtained by pressing a small beaker on top of the peat. The liquid portion was decanted; electrical conductivity (EC) of the filtrate was measured, in millimhos.cm^{-1} (Bower and Wilcox, 1965). It is assumed that the extracting method for peat is a measure of the ability of trees to extract nutrients from peat (Timmer and Parton, 1984). The same methods were used to determine nutrient concentrations in the peat extracts as in the foliar digests.

Data analysis

The data were subjected to two-way analysis of variance (SAS Institute, 1985): nutrient contents of needles, needle dry weights and nutrient concentrations in the peat samples, for the split plot experimental design. Means for sites (open forest, tundra), years (1984, 1985), and orientation (north, south, east, west) were further separated by Duncan's Multiple Range Test (SAS Institute, 1985).

Results

Open forest vs. tundra

Needles were 12% heavier and contained more N, P, Mg, and Mn in open forest compared to tundra white spruce. Concentrations of Ca, Fe and Zn were greatest in the tundra trees ($p < .01$) (Table 1).

TABLE 1
Mean oven dry weight (NWT) and nutrient concentration for needles of treeline white spruce from the open forest (OF) and tundra (T); n = 32.

TREATMENT	OF	T
VARIABLE		
NWT (g/100 needles)	0.25a	0.22b
N (%)	0.98a	0.88b
P (%)	0.11a	0.09b
K (%)	0.52a	0.47a
Ca (%)	0.51b	0.62a
Mg (%)	0.072a	0.057b
Na (ppm)	89.42a	98.59a
Cu (ppm)	5.84a	6.10a
Fe (ppm)	53.96b	64.64a
Zn (ppm)	76.31b	83.54a
Mn (ppm)	120.21a	41.98b

a,b Row values followed by different letters are significantly different for $p < .01$.

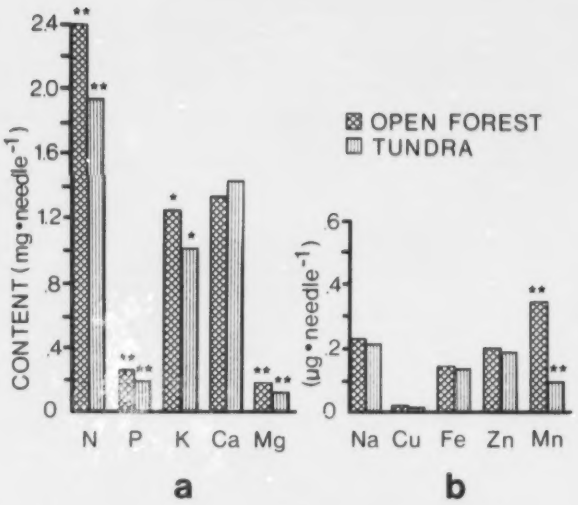


Figure 2. Mean foliage content of (a) macronutrients and (b) micronutrients for needles of treeline white spruce; n = 32; significant differences are indicated by one star ($p < .05$) or two stars ($p < .01$).

Needle content is the product of needle weight and nutrient concentration. Contents of N, P, Mg and Mn ($p < .01$) and K ($p < .05$) were higher in needles from open forest compared to tundra trees (Fig. 2).

Higher concentrations of N, P, K, and Mg ($p < .01$) and Na ($p < .05$) were found in saturated peat extracts from open forest than tundra sites (Fig. 3). No difference between

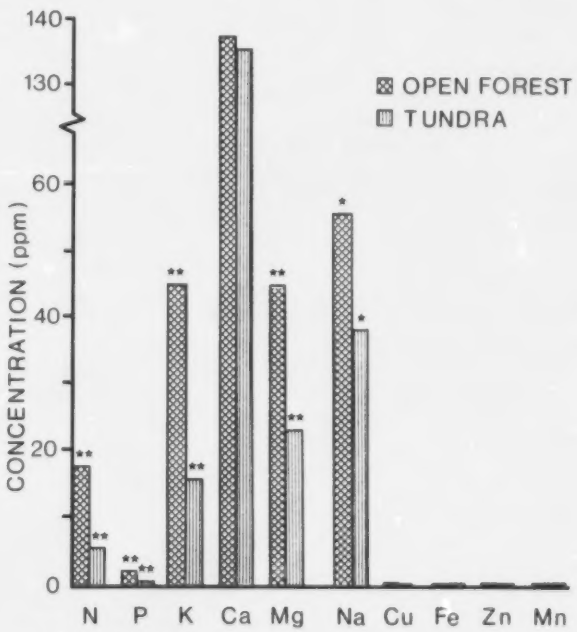


Figure 3. Mean nutrient concentration of peat extracts from Churchill, Manitoba; n = 16; significant differences are indicated by one star ($p < .05$) or two stars ($p < .01$).

TABLE 2
Mean oven dry weight (NWT) and nutrient concentration for needles of treeline white spruce, from 1984 and 1985; n = 32.

YEAR	1984	1985
VARIABLE		
NWT (g/100 needles)	0.27a	0.21b
N (%)	1.02a	0.83b
P (%)	0.08b	0.12a
K (%)	0.30b	0.70a
Ca (%)	0.75a	0.38b
Mg (%)	0.063a	0.066a
Na (ppm)	101.60*	86.41*
Cu (ppm)	5.62a	6.31a
Fe (ppm)	62.66a	55.95a
Zn (ppm)	97.66a	62.19b
Mn (ppm)	99.63a	62.56b

a,b Row values followed by different letters are significantly different for $p < .01$.
* values are significantly different, $p < .05$.

sites occurred in availability of Ca, the most abundant nutrient (>135 ppm). Less than 1 ppm of the micronutrients Cu, Fe, Zn and Mn were present in the peat extracts. The availability of soluble salts, measured by electrical conductivity (EC), was greater in saturated peat extracts from open forest (1.35) than tundra sites (0.92) ($p < .01$). The peat was less acidic on the tundra (7.5 pH) than in the open forest (6.7 pH) ($p < .01$).

1984 vs. 1985

Concentrations and contents of Ca, Zn, Mn and Na in needles were significantly higher in 1984 than in 1985 (Table 2 and Fig. 4). P and K were higher in 1984 than in 1985 by concentration, but were reversed by needle content ($p < .01$). Concentration of N and needle content of MG were significantly higher in 1984 than in 1985 (Table 2 and Fig. 4).

Since the peat samples were collected in the 1985 season, no data for nutrient availability were available for 1984.

Branch Orientation

Concentrations of P, and needle contents of P, K and Mg were significantly higher on the south side of the study trees than on the north (Table 3). Needles on the east contained more Fe than those on the north side, while concentrations of Ca were significantly lower on the east than on other sides of the study trees. No significant differences occurred among branch orientations for needle weight, needle concentrations, or contents of other nutrients.

Discussion

At the treeline, near Churchill, Manitoba, open forest trees consumed more N, P, Mg and Mn, and their needles contained more of these nutrients and K than tundra trees. Only three elements occurred in higher concentrations in tundra than open forest needles: Ca, Fe and Zn. The results indicate a difference in ability to consume essential elements, although rooting depth (1–10 cm) is similar between sites (Scott *et al.*, 1987).

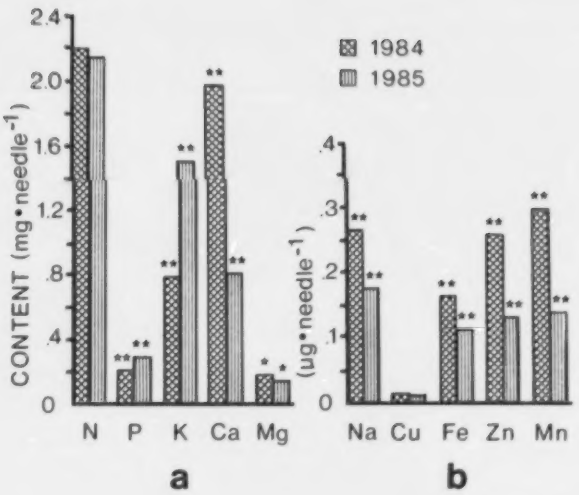


Figure 4. Mean foliage content of (a) macronutrients and (b) micronutrients for needles of treeline white spruce, comparing 2 years; n = 32; significant differences are indicated by one star ($p < .05$) or two stars ($p < .01$).

Open forest trees produced heavier needles and accumulated more biomass, thereby accumulating more nutrients than tundra trees. Foliar biomass for the open forest is approximately five times that for the tundra trees, based on my ocular estimates of numbers of branches and whorls, and recorded lateral branch elongation. This increases the nutrient differences between sites, supporting the hypothesis that nutrient availability restricts growth of tundra more than open forest trees. The nutrient content of needles was generally lower on the north than other sides of the study trees (Table 3), paralleling the presence of fewer and shorter branches (Fig. 1). The reduced nutrient content of needles indicated limitation of growth on the north side or limited growth affected nutrient uptake, either because of or as a result of wind, desiccation, snow abrasion, and reduced solar radiation.

Within the study trees and in the surrounding peat, Ca was abundant due to the underlying calcareous sand, marine clay and limestone. The nature of the substrate also causes high pH, found in the saturated peat extracts from both open forest and tundra sites. The slow rate of decomposition at the treeline, related to cool soil temperatures and low amounts of available C and N in the soil, ties up much N, P and K in soil organic matter (Moore, 1982). Significantly higher concentrations of N, P, K, Mg, Na and soluble salts (EC) were available to open forest than tundra trees from surrounding peat (Fig. 3). Significant differences in peat nutrient availability may be augmented by increased surface area on roots, through the development of more fine roots and myccorhiza. The pH of the peat extracts was significantly higher for tundra than open forest sites.

Both preceding and during the growing season, 1984 was much drier than normal, with one rainfall occurring late in August; 1985 was near normal for precipitation. Low precipitation during the growing season reduces growth in the arctic (Karlsson, 1985). P and K contents in the needles were highest during the normal year, 1985, while other nutrients

TABLE 3
Mean needle weight (NWT), nutrient concentration (% or ppm) and content in needles of treeline white spruce, by branch orientation (N = north, S = south, E = east and W = west); n = 16.

ORIENTATION	N	S	E	W
VARIABLE				
NWT (g/100 ndl)	0.22a	0.25a	0.25a	0.23a
N (%)	0.93a	0.93a	0.92a	0.93a
(mg/ndl)	2.04a	2.26a	2.25a	2.13a
P (%)	0.091b	0.109a	0.100ab	0.085b
(mg/ndl)	0.20b	0.26a	0.25a	0.20b
K (%)	0.46ab	0.56a	0.53ab	0.44b
(mg/ndl)	0.97b	1.28a	1.29a	1.03ab
Ca (%)	0.59a	0.61a	0.47b	0.58a
(mg/ndl)	1.35a	1.59a	1.21a	1.43a
Mg (%)	0.056b	0.065ab	0.071a	0.066ab
(mg/ndl)	0.12b	0.16a	0.18a	0.16a
Na (ppm)	95.84a	99.17a	89.47a	91.54a
(ug/ndl)	0.21a	0.25a	0.22a	0.22a
Cu (ppm)	5.53a	6.88a	5.31a	6.15a
(ug/ndl)	0.012a	0.016a	0.013a	0.015a
Fe (ppm)	55.84a	55.73a	63.34a	62.30a
(ug/ndl)	0.122b	0.135ab	0.155a	0.145ab
Zn (ppm)	80.20a	81.67a	82.09a	75.74a
(ug/ndl)	0.18a	0.21a	0.21a	0.18a
Mn (ppm)	81.88a	78.54a	84.37a	79.59a
(ug/ndl)	0.21a	0.22a	0.23a	0.21a

a,b Row values followed by different letters are significantly different for $p < .05$.

were highest during the drought year (Fig. 4). Thus uptake of P and K by plants was reduced when water, the transportation medium for nutrients, was limited in its availability. Since precipitation was lacking in 1984, nutrients were either stored in the needles from the previous growing season, soil moisture was adequate for transportation of nutrients, or nutrients were concentrated in the peat, requiring less water for uptake.

Since no nutrient levels have been reported previously for treeline white spruce, nutrient levels are compared with boreal forest white spruce (Morrison, 1974) in Table 4. The abundance of Ca and nutrient differences between years were discussed above. Mg concentrations remained at critical levels regardless of site or moisture regime. Concentrations of K were adequate for both sites, but low in the needles during the drought season. N and P were deficient for tree

TABLE 4
Mean nutrient concentration in white spruce needles from open forest (OF), tundra (T), and separate years (n = 32), compared to boreal forest levels reported by Morrison (1974).

					BOREAL FOREST		
	OF	T	1984	1985	Low	Critical	Adequate
VARIABLE							
N (%)	0.98	0.88	1.02	0.83	1.30	1.30–1.50	1.50
P (%)	0.11	0.09	0.08	0.12	0.14	0.14–0.18	0.18
K (%)	0.52	0.47	0.30	0.70	0.30	0.30–0.45	0.45
Ca (%)	0.51	0.62	0.75	0.38	0.10	0.10–0.15	0.15
Mg (%)	0.072	0.057	0.063	0.066	0.06	0.06–0.10	0.10

growth at the treeline, compared to the boreal forest. Needle appearance supports this: stunted, short, stiff and yellow-green to yellow (N deficiency; most severe in tundra trees); distinctly purple tinged when older and green or yellow-green when younger (P deficiency); and yellow tipped when current, followed by tip necrosis (Mg deficiency) (Morrison, 1974).

In conclusion, stunted growth of white spruce at the treeline may be a result of overall nutrient deficiency, compared to the boreal forest. Significant differences occurred in nutrient status between open forest and tundra sites, suggesting that nutrient availability in surrounding peat restricts growth more on tundra than on open forest trees. Foliar biomass and nutrient contents of needles were less for tundra compared to open forest, and on the north compared to the south sides of trees. Further investigations of nutrient status at the treeline are necessary to determine the relationships among climate, nutrient availability and moisture, and their effects on tree growth.

Acknowledgments

I am thankful to V. Timmer for guidance on this project, and the staff at Glendon Hall Research Laboratory for patience and laboratory assistance. I wish to thank P. Scott for field assistance and helpful comments, as well as D. Fayle and F. Lozano for their suggestions. The field work was supported in part by an N.S.E.R.C. grant to R. Hansell.

References

Allen, S.E. 1974. Chemical analysis of ecological materials. New York: John Wiley and Sons.

Bentley, C.V. 1985. Growth fluctuations of treeline white spruce and tamarack. Report to Ontario Ministry of Natural Resources. Contract No. 375. 80 p.

Bower, C.A. and Wilcox, L.V. 1965. Soluble salts. In: Black, C.A., ed. Methods of Soil Analysis. Part 2. 933–951.

Bremner, J.M. 1965. Total nitrogen. In: Black, C.A., ed. Methods of Soil Analysis. Part 2. 1149–1178.

Goldstein, G.H., Brubaker, L.B., and Hinckley, T.M. 1985. Water relations of white spruce (*Picea glauca* (Moench) Voss) at tree line in north central Alaska. Canadian Journal of Forest Research 15:1080–1087.

Grewling, T. 1976. Chemical analysis of plant tissue. Search 6:1–35.

Hadley, J.L. and Smith, W.K. 1983. Influence of wind exposure on needle desiccation and mortality for timberline conifers in Wyoming, U.S.A. Arctic and Alpine Research 15(1):127–135.

Karlsson, P.S. 1985. Effects of water and mineral nutrient supply on a deciduous and an evergreen dwarf shrub: *Vaccinium uliginosum* L. and *V. vitis-idaea* L. Holarctic Ecology 8:1–8.

Kullman, L. 1986. Recent tree-limit history of *Picea abies* in the Swedish Scandes. Canadian Journal of Forest Research 16:761–771.

Leaf, A.L. (1973). Plant analysis as an aid in fertilizing forests. In: Walsh, L.M. and Beaton, J.D., eds. Soil Testing and Plant Analysis. Soil Science of America, Inc. 427–454.

Lowther, J.R. 1980. Use of a single sulphuric acid-hydrogen peroxide digest for the analysis of *Pinus radiata* needles. Communications in Soil Science and Plant Analysis 11(2):175–188.

Moore, T.R. 1982. Nutrients in subarctic woodland soils. Le Naturaliste Canadien 109:523–529.

Morrison, I.K. 1974. Mineral nutrition of conifers with special reference to nutrient status interpretation: a review of literature. Publication No. 1343. Department of Environment. 74 p.

Payette, S. 1974. Classification écologique des formes de croissance de *Picea glauca* (Moench) Voss et de *Picea mariana* (Mill.) B.S.P. en milieux subarctiques et subalpins. Le Naturaliste Canadien 101:893–903.

Rouse, W.R. 1984. Microclimate of arctic tree line 2. Soil microclimate of tundra and forest. Water resources Research 20(1):67-73.

SAS Institute. 1985. SAS introductory guide. 3rd ed. Cary, N.C.: SAS Institute, Inc. 99 p.

Scott, P.A., Bentley, C.V., Fayle, D.C.F. and Hansell, R.I.C. 1987. Shoot elongation of treeline white spruce: defining the treeline at Churchill, Manitoba, with crown forms. Arctic and Alpine Research 19(2): in press.

Timmer, V.R. and Parton, W.J. 1984. Optimum nutrient levels in a container growing medium determined by a saturated aqueous extract. Soil Science and Plant Analysis 15(6):607-618.

Tranquillini, W. 1979. Physiological ecology of the alpine timberline. Berlin: Springer-Verlag. 137 p.

Yoshino, M.M. 1973. Wind-shaped trees in the subalpine zone in Japan. Arctic and Alpine Research 5:115-126.

CORRELATIONS BETWEEN PLANT COVER, BIOMASS AND SOIL MOISTURE PARAMETERS FROM NINE ARCTIC SITES

Jean-François Bergeron

Department of Botany, University of Toronto, Erindale Campus, Mississauga, Ontario L5L 1C6

Level: Master's

Abstract

The relationships between the following parameters: i) plant cover and biomass, ii) biomass and soil moisture, and plant cover and soil moisture are discussed for the plant communities of three Low Arctic areas and six High Arctic areas. Several authors (Svoboda, 1974, Webber, 1978, Bliss and Svoboda, 1984) suggested that significant correlations between the aforementioned pairs of parameters exist. In this study vascular plant cover, aboveground biomass, gravimetric and volumetric soil moisture were correlated by using the product-moment correlation and the Spearman's rank correlation. Our results indicate that the above correlations may not necessarily apply for the whole Arctic. The variations in growth forms are probably responsible for the lack of significant correlations on a large geographical scale.

A positive correlation between plant cover and biomass was observed for four out of seven localities studied. However, the shrub-dominated communities did not support this trend. The cover values should be used with caution as an indicator of the standing crop. The data of vascular standing crop and soil moisture of four authors suggested that the highest phytomass values are found in mesic sites while the lowest occur in dry and wet sites. The data from two locations indicated that the last relationship cannot be generalized for the whole Arctic. Vascular cover and soil moisture were positively correlated for five out of eight locations. This relationship is valid where the vascular plants constitute the major components in plant communities, such as some polar oases of the High Arctic. A greater number of biomass, plant cover and soil moisture data from the Low and the High Arctic are needed to verify the presented relationships.

Key words: Plant communities, plant cover, biomass, soil moisture, Low Arctic, High Arctic.

Résumé

Les relations entre les paramètres suivants: i) pourcentage de recouvrement végétal et biomasse, ii) biomasse et drainage du sol, iii) pourcentage de recouvrement et drainage du sol, sont etudiées pour les communautés végétales de trois stations du Bas-Arctique et six stations du Haut-Arctique. Des corrélations significatives entre les paramètres énumerés ci-haut ont été suggerées par plusieurs auteurs (Svoboda, 1974, Webber, 1978, Bliss et Svoboda, 1984). Dans ce travail, le pourcentage de recouvrement en espèces vasculaires, la biomasse au-dessus du sol, et les valeurs gravimétriques ou volumétriques d'humidité du sol ont été comparées à l'aide de la corrélation linéaire de Pearson, et de la corrélation de Spearman. Nos résultats suggèrent que les corrélations discutées ne sont nécessairement pas valables pour toutes les communautés arctiques. La validité des corrélations à une grande échelle géographique est reliée à la variabilité dans la composition en formes de croissance, à l'intérieur des communautés végétales.

Une corrélation significative entre le pourcentage de recouvrement et la biomasse a été notée pour quatre des sept stations. Cependant cette relation ne s'applique pas aux communautés dominées par des arbustes. Les valeurs de pourcentage de recouvrement doivent être utilisées prudemment lorsqu'elles sont considérées comme indicatrices de biomasse. Les données de biomasse et d'humidité du sol de quatre auteurs indiquent que les valeurs de biomasse les plus élevées sont associées aux sites mésiques alors que les valeurs les plus basses sont associées aux sites hydriques et xériques. Ceci ne peut pas être généralisé pour tout l'Arctique, en effet deux stations contredisent la relation. Le pourcentage de recouvrement et le drainage du sol présentent une corrélation significative pour cinq stations parmi huit. Cette corrélation est vérifiée lorsque les communautés sont principalement composées de taxons vasculaires, tel que dans les oasis polaires du Haut-Arctique. Des données plus nombreuses sur le régime hydrique des sols, la biomasse et le pourcentage de recouvrement des communautées végétales, nous permettrait probablement de généraliser certaines corrélations à l'échelle du Bas et du Haut-Arctique.

Mots-clés: Communautés végétales, recouvrement végétal, biomasse, humidité du sol, Bas-Arctique, Haut-Arctique.

Introduction

Several vegetation studies in arctic North America show correlations between above-ground standing crop and soil moisture, standing crop and plant cover (Svoboda (1974); Webber (1978); Bliss and Svoboda (1984)). These correlations were positive (and mostly significant) for the specific sites studied. A comparison of the correlations for the three

TABLE 1
Cover-soil moisture, soil moisture-biomass, biomass-cover correlation coefficients for nine arctic sites.

Author	Locality	Soil moisture method ②	n	r for cover: soil moisture	r for soil moisture: biomass	r for biomass: cover
Bergeron, 1985	Nouveau-Québec 62°N 74°W	subjective	20	r_s=0.783* b	-	-
Bliss and Svoboda, 1984	Western Queen Elizabeth Is. 75°N 108°W, 77°N 101°W, 76°N 102°W	-	8	-	-	r=0.810*
Freedman et al., 1983	Ellesmere Is. Alexandra Fiord 78°53'N75°55'W	subjective	13	r_s=0.482	r_s=0.125	r=0.563*
Gould, 1965	Ellesmere Is. Lake Hazen 81°49'N71°18'W	gravimetric	7	r=0.840*	r=0.054	r=0.182
Miller and Alpert, 1984	Bathurst Is. 75°43'N98°25'W	gravimetric	10	r=0.076	-	-
Muc, 1986 (in press)	Ellesmere Is. Alexandra Fiord 78°53'N75°55'W	subjective	13	r_s=0.837*	r_s=0.451	r=0.71*
Reznicek and Svoboda, 1982	Southampton Is. 64°12'N83°22'W	gravimetric	6	r=0.875*	r=0.385	r=0.086
Svoboda, 1974	Truelove Lowland, Devon Is. 75°33'N84°40'W	gravimetric	3	r_s=1.0*	r_s=1.0*	r= 0.968,n=8* 0.767,n=9* 0.664,n=9*
Webber, 1978	Barrow, Alaska 71°18'N156°40'W	gravimetric	8	r=0.516	r=0.460	r=0.545

② all the gravimetric soil moisture values were expressed in percentage, except the values of Miller and Alpert, 1984 expressed in g H_2O / g dried soil

* $P<0.05$ b) r_s : Spearman's coefficient

parameters among the various studies should reveal whether generalizations can be made for the Arctic as a whole.

In this paper we undertake a comparison of correlations between standing crop, plant cover and soil moisture from nine study sites throughout the Arctic (62° to 82° N) in order to determine whether a general pattern exists.

Methods

The nine study sites included three low arctic and six high arctic areas (Table 1). Gravimetric and volumetric methods were used to determine the soil moisture (Table 1). The three pairs of parameters: i) plant cover and biomass, ii) biomass and soil moisture, iii) plant cover and soil moisture, were correlated using the product-moment correlation (r) and the Spearman's rank correlation (r_s) for the semi-quantitative values of soil moisture. All biomass and plant cover measurements were of vascular plants only.

Results and discussion

Plant cover and biomass

A correlation between biomass and plant cover has been demonstrated by several authors (Table 1). Bliss and Svoboda (1984) obtained a correlation coefficient of 0.810 ($p < 0.05$) for polar semi-desert communities (herb and cryptogam dominated) sampled in three different areas of the Queen Elizabeth Islands. They suggested that cover values can be a good indicator of the standing crop, especially when combined with a partial sampling. The raised beach communities of Truelove Lowland, Devon Island, studied by Svoboda (1974) showed a high level of correlation, $r = 0.968, 0.767, 0.664$, (all $p < 0.05$), respectively from the crest, the slope and the transitional zone. Muc and Svoboda (1985) found a significant correlation ($r = 0.71$, $p < 0.01$) for the polar oasis communities of Alexandra Fiord, Ellesmere Island. Freedman *et al.* (1983), sampling the same community types at Alexandra Fiord, published a different set of data, but the corresponding correlation was still significant, $r = 0.563$, ($p < 0.05$).

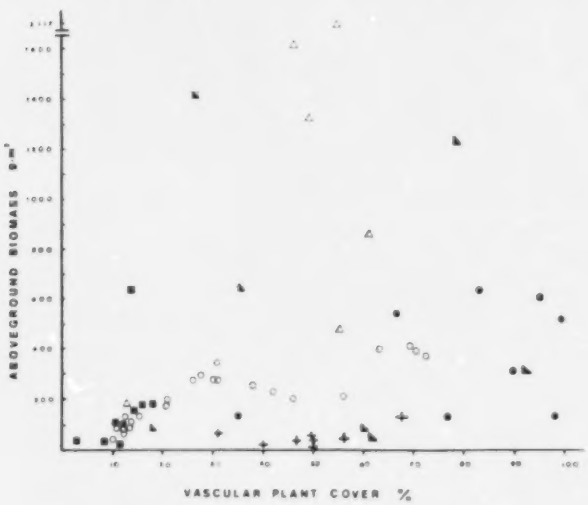


Figure 1. Correlation between above-ground biomass and vascular plant cover from the data of Bliss and Svoboda, 1984 (□); Freedman *et al.*, 1983 (●); Gould, 1985 (◮); Reznicek and Svoboda, 1982 (△); Svoboda, 1974 (○); and Webber, 1978 (+). $n = 61$, $r = 0.282$, $p < 0.05$.

However the cover and biomass data of Reznicek and Svoboda (1982) and Gould (1985) did not support the biomass:plant cover correlation. The r coefficients were 0.086 and 0.182 respectively. The shrub communities of Southampton Island (studied by Reznicek and Svoboda (1982)), having the highest biomass values, had a cover value (50.2%) comparable to the average cover value of all the communities (46.8%). Of seven communities examined by Gould (1985), the three with the highest biomass values had an important shrub component (72–100% of the standing crop). Since these communities did not have the highest cover values, but an average value ($x \pm$ s.d.; 46.5 + 28.0%) slightly lower than the average cover value of all the communities (56.5 ± 30.1), the correlation cannot hold. The data from the shrub communities of Reznicek and Svoboda (1982) showed the same trend. The correlation was not significant for the data of Webber (1978). Muc and Svoboda (1985), discussing the woody component in low and high arctic vegetation, mentioned that a lowland sedge meadow had greater plant cover but lower phytomass than a dwarf shrub or heath community. This would suggest that for the communities where shrubs dominate among the other growth forms, the biomass and the plant cover are not necessarily correlated. The previous cases illustrated that the correlation of biomass and cover was not entirely applicable to all arctic communities. Therefore we must be careful about the use of cover values as biomass indicators, which was suggested by Bliss and Svoboda (1984).

Biomass and soil moisture

The positive correlation between soil moisture and vascular above-ground biomass was not strongly demonstrated in the literature. Reznicek and Svoboda (1982) established a correlation between total biomass and moisture, although the similar correlation with vascular biomass was not significant ($r = 0.385$). The correlation from the data of Svoboda (1974) was significant although for a very limited number of communities ($n = 3$). According to Webber (1978), increased primary production was shown to be positively correlated with soil moisture levels. However for the monocotyledon-dominated communities studied by the same author, the vascular biomass:soil moisture correlation was not significant. The low range of vascular biomass (4.8–118.6 g/m^2) did not show any relationship with the extreme soil moisture values (77–500%). Webber (1974), Komarkova and Webber (1980), and Muc and Svoboda (1985) stated that the highest phytomass values were associated with mesic sites and lower values were observed in xeric and hydric situations. In effect the highest phytomass values in the data of Freedman *et al.*, (1983); Gould (1985); and Muc and Svoboda (1985) were located in the middle of the moisture gradient. This last statement was confirmed for *Salix* communities which have maximum phytomass in mesic habitats, although biomass and soil moisture are expected to be correlated in *Dryas* and *Cassiope* communities better developed in dry habitats (Muc and Svoboda (1985)).

Plant cover and soil moisture

The relationship between vascular plant cover and soil moisture is not indicated in the literature. Miller and Alpert (1984), referring to Vitt and Pakarinen (1977); Flock (1978); and Alpert and Oechel (1982), mention that an increase in plant cover, especially for bryophytes, is related to an increase in soil moisture. The vascular cover data of Miller and Alpert (1984) for Bathurst Island did not corroborate the correlation ($r = 0.296$). For the data of Webber (1978), the correlation of vascular cover and soil moisture was not significant ($r = 0.464$). The four communities (dominated by *Carex*, *Dupontia* and *Arctophila*) with the highest moisture content (290–500%), included the lowest and the highest vascular plant covers among the communities. For all eight communities, the bryophyte cover was noticeable, it represented from 30.2 to 47.4% of the total plant cover. But the correlation between bryophyte cover and soil moisture was not significant. The extremely high values of soil moisture observed in those monocotyledon-moss communities were not correlated with either plant cover or biomass. A greater number of monocotyledon-moss communities from other arctic locations would indicate whether the plant cover:soil moisture correlation exists or not.

Contrarily in another low arctic site, Asbestos Hill, Nouveau-Québec, the highest values of vascular cover were characteristic of the wettest communities (snowbank, bog and seepages) dominated by *Carex* and *Salix*. The calculated coefficient r_s was 0.783 ($p < 0.01$). The correlation coefficients obtained from the data of Gould (1985); and Reznicek and Svoboda (1982) were both significant, $r = 0.840$ ($p < 0.05$) and $r = 0.875$ ($p < 0.05$) respectively, and in both studies vascular plant cover was important, with ratios of vascular cover to total plant cover respectively 1:1.37 and 1:1.40. The significant correlation ($r_s = 1.0$, $p < 0.05$) for the raised beach communities of Truelove Lowland was explained by the growth forms (Svoboda, 1974). An increase in soil moisture, from xeric to mesic conditions in this case, was reflected by a cover increase of few dominating woody species such as *Dryas integrifolia*, *Saxifraga oppositifolia*, and *Salix arctica*. The communities investigated by Muc and Svoboda (1985) verified the correlation ($r = 0.840$, $p < 0.05$) and vascular plants constituted the major components of these communities.

The relationship between vascular cover and biomass found in polar oases such as Alexandra Fiord, could be observed in other polar oases since vascular plants are well represented in these environments. This relationship could not be noticeable in polar deserts and polar semi-deserts because of their low vascular plant cover (Bliss, 1981) and important cryptogam cover (Bliss and Svoboda, 1983; Bliss *et al.*, 1983). Finally the correlation between vascular cover and soil moisture is significant when vascular plants dominate in arctic communities.

Correlations combining several sites

A correlation combining the plant cover and soil moisture data of three comparable sites was not significant ($r = 0.191$, $n = 19$). The correlation of biomass and soil moisture from the data of Reznicek and Svoboda (1982); Webber (1978); and Gould (1985) was not significant either ($r = -0.375$, $n = 19$). The data of Webber (1978) influenced considerably the combined correlation of soil moisture and biomass, and soil moisture:plant cover. As we calculated previously, the eight pairs of values, from Webber's data, were not correlated partly because of the extreme values of soil moisture. Knowing that plant cover and soil moisture data of five sites out of eight were correlated (according to r and r_s), we can suggest that the combined correlation would be made significant by removing the data of Webber (1978), and by computing a greater number of pairs (for which the soil moisture is expressed in percentage) from new arctic sites. The biomass and plant cover data of Bliss and Svoboda (1984); Freedman *et al.* (1983); Gould (1985); Reznicek and Svoboda (1982); Svoboda (1974); and Webber (1978) combined together showed a significant correlation, $r = 0.282$, $p < 0.05$ (Fig. 1). A variety of growth forms: deciduous and evergreen shrubs, monocotyledons, cushion dicotyledons and herbs showed their above-ground biomass values (4.8–2117 g/m^2) correlated to a complete range of vascular cover (3.8–99%). In the correlation, most of the communities (56 out of 61) had a biomass lower than 850 g/m^2. The five remaining communities with a biomass between 1250 and 2117 g/m^2 were shrub communities (*Dryas* and *Cassiope* dominated). Those have already been shown not to conform with the biomass:cover relationship. The level of significance of this correlation is considerably increased ($r = 0.395$, $p < 0.05$) when only the communities having a biomass less than 850 g/m^2 are considered. Low arctic shrub communities are then excluded from this relationship.

Conclusions

In spite of the limitations in the number of examined arctic sites and in the number of correlated communities per site the following relationships were exposed.

- Above-ground vascular biomass was correlated with vascular cover, as four (out of seven) arctic sites indicated. However, the cover data of Gould (1985) and Reznicek and Svoboda (1982) suggested that this correlation is not necessarily applicable when shrub cover is significant in communities, therefore the cover values should be used with caution as an indicator of the standing crop.

- The correlation between above-ground vascular biomass and soil moisture was not significant for five out of six arctic sites. The distribution of the phytomass values within the moisture gradient for the compared communities was in agreement with the relationship observed by Webber (1974); Komarkova and Webber (1980); and Muc and Svoboda (1985). The highest phytomass values correspond to mesic sites and the lowest values to the dry and wet extremities of the moisture gradient.

- For five out of eight arctic sites, vascular cover and soil moisture were correlated. The relationship is predictable for sites having a dominant vascular cover. Polar oases are expected to corroborate this correlation whereas polar deserts and polar semi-deserts are not.

- By combining data from three arctic areas, correlations between soil moisture and vascular cover, and soil moisture and biomass were not significant. However, the correlation between biomass and vascular cover, calculated from the values of six arctic sites, was

significant. The influence of shrub communities (having a biomass greater than 850 g/m^2) was discussed in the light of this correlation.

Finally, the applicability of the presented relationships is related to the importance of the vascular cover and to the growth form composition in communities. More cover, soil moisture and biomass data per site and a greater number of low and high arctic sites are needed to confirm the discussed relationships.

Acknowledgments

I would like to thank Dr. Josef Svoboda, Greg Henry, and Gord Hart who made several helpful suggestions.

References

Alpert, P., and Oechel, W.C. 1982. Bryophyte vegetation and ecology along a topographic gradient in montane tundra in Alaska. Holarctic Ecology 5:99–108.

Bergeron, J.-F. 1985. Végétation de la région de Baie-Deception et Asbestos Hill, Québec arctique. Unpublished manuscript. Laboratoire de télédétection, Département de Géographie, Université de Montréal. 56 p.

Bliss, L.C. 1981. North American and Scandinavian tundras and polar deserts. In Tundra ecosystems: A comparative analysis (L.C. Bliss, O.W. Heal, and J.J. Moore, Eds.). Cambridge University Press. 8–24.

Bliss, L.C., *et al.* 1984. Polar deserts, their plant cover and plant production in the Canadian High Arctic. Holarctic Ecology 7:301–320.

Bliss, L.C. and Svoboda, J. 1984. Plant communities and plant production in the western Queen Elizabeth Islands. Holarctic Ecology 7:325–344.

Flock, J.W. 1978. Lichen-bryophyte distribution along a snow cover-soil moisture gradient, Niwot Ridge, Colorado. Arctic and Alpine Research 10:31–47.

Freedman, B. 1983. Physical and ecological characteristics of Alexandra Fiord, a high arctic oasis on Ellesmere Island, Canada. In proceedings of the fourth international conference of permafrost. National Academy Press. 301–304.

Gould, A.J. 1985. Plant communities of the Lake Hazen area, Ellesmere Island, N.W.T. M.Sc. thesis, Department of Botany, University of Toronto, Toronto.

Komarkova, V., and Webber, P.J. 1980. Two low arctic vegetation maps near Atkasook, Alaska. Arctic and Alpine Research 12:447–472.

Miller, N.G., and Alpert, P. 1984. Plant associations and edaphic features of a high arctic mesotopographic setting. Arctic and Alpine Research 16(1):11–24.

Muc, M., and Svoboda, J. 1986. Community and habitat variations in aboveground vascular phytomass of a high arctic polar oasis. In Ecology of a high arctic lowland oasis, Alexandra Fiord (78°53′ N, 78°55′ W), Ellesmere Island, N.W.T., Canada (J. Svoboda and B. Freedman, Eds.). Toronto: Department of Botany, University of Toronto (in press).

Reznicek, S.A., and Svoboda, J. 1982. Tundra communities along a microenvironmental gradient at Coral Harbour, Southampton Island, N.W.T. Naturaliste canadien 109:583–595.

Svoboda, J. 1974. Primary production processes within polar semi-desert vegetation, Truelove Lowland, Devon Island, N.W.T. Ph.D. thesis, Department of Botany, University of Alberta, Edmonton.

Vitt, D.H., and Pakarinen, P. 1977. The bryophyte vegetation, production, and organic components of Truelove Lowland. In Truelove Lowland, Devon Island, Canada: a high arctic ecosystem (L.C. Bliss, ed.). Edmonton: University of Alberta. 225–244.

Webber, P.J. 1974. Tundra primary productivity. In Arctic and alpine environments (J.D. Ives and R.G. Barry, eds.). London: Methuen. 445–473.

Webber, P.J. 1978. Spatial and temporal variation of the vegetation and its production, Barrow, Alaska. In Vegetation and production ecology of an alaskan tundra (L.L. Tieszen, ed.). New York: Springer-Verlag. 37–112.

BIOCHEMICAL DIFFERENCES BETWEEN TWO RELATED SPECIES OF *LEPTODIAPTOMUS* (COPEPODA)

Marc G. Boileau and Paul D.N. Hebert

Department of Biology, University of Windsor, Windsor, Ontario, N9B 3P4

Level: M. Boileau, Ph.D.

Abstract

The distinctiveness of the calanoid copepods *Leptodiaptomus tyrrelli* Poppe 1888 and *L. pribilofensis* Juday and Muttkowski 1915 has been questioned since the latter taxon was described. *L. tyrrelli* is widely distributed in montane and low arctic habitats, while *L. pribilofensis* is most common in Alaska and northwestern Canada. Cellulose acetate electrophoresis was used to estimate the amount of genetic divergence between these two taxa because of its proven utility on very small organisms. The genetic identity (I) was determined by the analysis of 11 enzyme systems representing 18 presumptive loci. The estimate of I from comparison of over 400 individuals indicated a genetic identity of 0.63 between the two taxa and revealed the presence of 4 diagnostic enzyme loci. Such marked divergence strongly suggests that *L. tyrrelli* and *L. pribilofensis* are distinct taxa.

Key words: *Leptodiaptomus*, systematics, electrophoresis, biochemical genetics.

Résumé

On a mis en question le caractère distinctif des copépodes calanoïdes *Leptodiaptomus tyrelli* Poppe 1888 et *L. pribilofensis* Juday & Mattkowski 1915, depuis que ce dernier taxon a été décrit. *L. tyrelli* est largement répandu dans les biotopes des zones montagnarde et proche-arctique, alors que *L. pribilofensis* est très commun, en Alaska et dans le Nord-ouest canadien. Les auteurs ont utilisé l'électrophorèse sur acétate de cellulose pour évaluer l'ampleur de la divergence génétique entre ces deux taxons, en raison de son efficacité pour l'étude des organismes minuscules. Ils ont évalué l'identité génétique (I) des deux taxons par l'analyse de onze systèmes enzymatiques représentant 19 localisations présumées. La comparaison de 400 individus leur a permis de fixer à 0,63 le taux d'identité des deux taxons et de mettre en relief la présence de 4 localisations enzymatiques diagnostiques. Cette divergence bien marquée confirme que *L. tyrelli* et *L. pribilofensis* sont des taxons distincts.

Mots-clés: *Leptodiaptomus*, génétique biochimique, polymorphisme des enzymes.

Introduction

Systematists have traditionally relied mainly upon morphological criteria to distinguish taxa, but many groups of animals have defied satisfactory definition. Multi-locus enzyme electrophoresis has been recognized as a powerful systematic tool because it enabled the direct study of the genetic basis of taxonomically important characters (Avise 1975; Ayala 1983). The technique has been used widely since 1963, over a broad range of taxa (Powell 1975; Nevo 1978). Indices of electrophoretic identity between taxa have been largely concordant with traditional systematic conclusions. However, electrophoretic analysis has proven invaluable in the discrimination of morphologically similar or "sibling species" (Manwell and Baker 1963; Manwell *et al.* 1967; Ayala *et al.* 1970; Ayala and Powell 1972; Dowling and Moore 1985; Hebert and Loaring 1986).

Very few studies in biochemical genetics have concerned the copepod crustaceans due to their small size and the freshwater copepods are unstudied despite the existence of many systematic uncertainties. Since 1915 there has been confusion regarding the taxonomic status of *Leptodiaptomus tyrrelli* Poppe 1888 and *L. pribilofensis* Juday and Muttkowski 1915. Marsh (1915) and Kincaid (1953) questioned the distinctiveness of *L. pribilofensis* as did the treatise by Marsh (1918) which formed the basis of copepod identification for many years. *L. tyrrelli* is widespread in montane and subarctic habitats in western Canada east to Labrador. It apparently does not co-occur with *L. pribilofensis* (personal observation), which is less widely distributed in Alaska and northwestern Canadian arctic habitats. Some early surveys of northern Canada (Marsh 1920; Carl 1940; Hooper 1947) are unclear as to which taxon was found due to this confusion. More recent treatments by Pennak (1953) and Wilson (1959) recognize the two taxa as distinct.

Animals of both taxa are less than 2 mm long. Cellulose acetate electrophoresis is an excellent technique for allozyme analysis of very small organisms and this study employs this technique to determine the genetic relatedness of *L. tyrrelli* and *L. pribilofensis*.

Materials and methods

Live animals of *Leptodiaptomus tyrrelli* were sampled on July 25, 1986 from a large tundra pond (Pond T37; mean depth = .25 m, area = 3330m^2) near Churchill, Manitoba and shipped to Windsor where they were immediately frozen in liquid nitrogen for later analysis. Patterns of allozyme variation in this species have been under detailed investigation at this location for 4 years. The enzymes reported in this study have been surveyed in several other populations at Churchill with results that were consistent with those reported in this survey. *L. pribilofensis* were collected August 12, 1986 from a very large sphagnum pond (approx. area = 6500 m^2) located approximately 4.0 km from termination of the Dempster Highway near Inuvik, N.W.T. Animals were analysed immediately for 11 enzymes [Phosphoglucose isomerase (PGI); Phosphoglucomutase (PGM); Glutamate oxaloacetate transaminase (GOT); Mannose phosphate isomerase (MPI); Isocitrate dehydrogenase (IDH); Phenylalanine proline peptidase (PEP D); Arginine phosphokinase (APK); Fumarate hydratase (FUM); Malate dehydrogenase (MDH); Amylase (AMY); Aldehyde dehydrogenase (AO)].

Additional animals where collected on August 27 and shipped alive to Windsor where comparative analysis of the two species was completed by September 5.

All animals were homogenized and electrophoresed for appropriate times following the methods of Hebert and Beaton (1986). Due to the very small body size of *L. pribilofensis*, individual animals were analysed for a single enzyme only. Reference animals from Churchill were run simultaneously on gels with Inuvik animals to ascertain the relative mobilities of allozyme variants. Bands with similar mobilities were considered to be the product of the same allele.

Enzyme systems (presumptive loci) are referred to by numbers, the most anodal systems being number 1 with slower systems being numbered in succession. Alleles are similarly numbered so that the fastest allele found in the fastest running system of MDH for example would be MDH-1^1, MDH-1^2 the next fastest and so on.

Polymorphic enzyme phenotypes where N > 10 were compared to Hardy-Weinberg expectations and gene frequencies were determined by direct count. Genetic identity (I) was determined using the formula,

$$I = \frac{J_{xy}}{(J_x J_y)^{1/2}}$$

where J_{xy}, is the arithmetic mean of the product of common gene frequencies at each locus, and J_x and J_y are the mean gene locus identities of species x and y respectively (Nei 1972).

Results

Eleven enzymes representing 18 presumptive enzyme loci were surveyed in 479 animals from both taxa. Eight loci were monomorphic for the same allele in both taxa: AO; AMY; MDH-1; FUM; APK-1; APK-3; APK-4; APK-5. Two loci were fixed for different alleles in each taxon (MDH-2), and APK-2). Two loci, GOT-2 and IDH-2 were polymorphic in *L. pribilofensis* and monomorphic in *L. tyrrelli*, while one locus (APK-6) was polymorphic only in the latter species (Table 1). Two of these polymorphic systems shared no common alleles (GOT-2) and APK-6).

Quaternary enzyme structure, inferred from the heterozygote phenotypes, was dimeric in PGI, GOT and PEP C and monomeric in PGM, MPI, APK, and IDH. These results are consistent with those of other crustaceans in all enzymes except IDH. Heterozygotes at both IDH loci in *Leptodiaptomus* were double-banded. This pattern has been found in other freshwater copepods (personal observation) but other Crustacea typically show three banded heterozygotes which implies a dimeric quaternary structure.

Leptodiaptomus pribilofensis and *L. tyrrelli* were polymorphic at 39% and 33% of the 18 loci, respectively. Eleven polymorphic enzyme phenotype distributions were compared to those expected by Hardy-Weinberg expectations and none differed significantly (P = .05) from expectations (Table 1). Estimates of individual heterozygosity (H_e) for *L. pribilofensis* and *L. tyrrelli* were 0.18 ± 0.06 and 0.16 ± 0.06

TABLE 1
Gene frequencies, genetic identity and chi square statistics for polymorphic enzyme loci for two closely related species of *Leptodiaptomus* from northern Canada.

Enzyme		Allele	Gene Frequencies L. pribilofensis	L. tyrrelli	I_N
PGI	N		24	12	
	X^2		0.198	0.717	0.874
		1	.92	.62	
		2	.04	.38	
		3	.04	—	
PGM	N		24	12	
	X^2		1.826	1.333	0.249
		1	.10	—	
		2	.48	.04	
		3	.27	.08	
		4	.08	.45	
		5	.06	.13	
GOT	N		24	12	
	X^2		0.325	—	0.0
		1	.10	—	
		2	.90	—	
		3	—	1.0	
MPI	N		24	6	
	X^2		1.850	—	0.327
		1	.44	.08	
		2	.44	—	
		3	.12	.59	
		4	—	.33	
IDH-1	N		24	12	
	X^2		10.211	3.247	0.866
		1	.33	.21	
		2	.29	.29	
		3	.27	.17	
		4	.11	.33	
IDH-2	N		23	12	
	X^2		2.858	—	0.300
		1	.20	—	
		2	.48	—	
		3	.17	1.0	
		4	.15	—	
APK-6	N		18	6	
	X^2		—	—	0.0
		1	1.0	—	
		2	—	.17	
		3	—	.83	
PEP D	N		24	24	
	X^2		.588	1.455	0.241
		1	—	.80	
		2	.90	.20	
		3	.10	—	

respectively. The distribution of individual locus identities (I_N) at all 18 loci was U-shaped (Fig. 1) and the average I between the two taxa was 0.630 which corresponds to a genetic distance (D) of 0.462 ± .040.

Discussion

Invertebrates generally show high levels of allozyme variation and crustaceans are no exception. Non-insect invertebrates show individual heterozygosities averaging 10% (Nevo 1978), compared to 7% in Crustacea (Hedgecock *et al.* 1982). The genus *Drosophila* is outstanding among the invertebrates with H_e = 14% which is as variable as any group studied. However, the marine copepods which have been studied are more variable than most Crustacea (H_e = .12; Hedgecock *et al.* 1982) and the average heterozygosity of 17% observed in this study suggest that the freshwater Copepoda are also extremely variable.

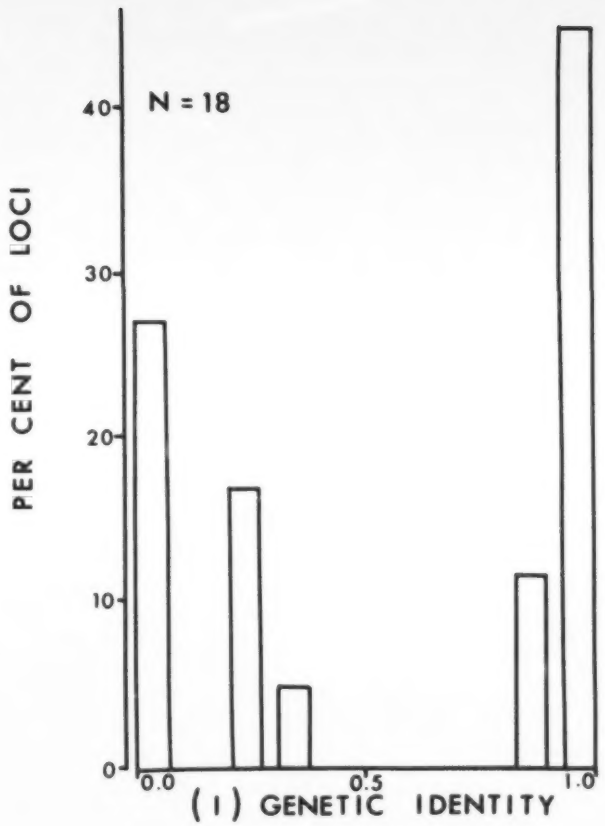


Figure 1. Distribution of single locus genetic identity (I) values between *L. tyrrelli* and *L. pribilofensis* at 18 electrophoretic enzyme loci.

The taxonomic distinctiveness of *L. tyrrelli* and *L. pribilofensis* has been questioned in the past. Although recent workers have considered them separate species on the basis of morphological characters, calanoid morphology is quite plastic. However, the allozyme data provide strong evidence that these two taxa are reproductively isolated. Specifically the low genetic similarity of the two taxa (0.63) and the U-shaped distribution of identities correspond to the value found between other congeneric Crustacea (Hedgecock *et al.* 1982). The estimate of genetic similarity is conservative because only 25% of real genetic base pair differences are detected by electrophoresis (Nei 1975) and the assumed homology of alleles with equal mobility products is a conservative criterion (Avise 1975). There is reason, for example, to believe that there might be a lack of homology in MPI where, although alleles 1 and 3 apparently have the same mobility, the spacing of the other electromorphs within each species is very different.

Leptodiaptomus pribilofensis and *L. tyrrelli* probably diverged from a common ancestor approximately 1.4 million years ago (conservatively estimated using Nei's 1975 formula $t = 5 \times 10^6 D$, where $D = -\ln I$). The predominance of *Leptodiaptomus pribilofensis* in northwestern Canada and Alaska suggests it may have been isolated in the Beringian refuge during maximum glaciation. Both species may still be expanding their range through the

Arctic since deglaciation. The more widespread distribution of *L. tyrrelli* compared to *L. pribilofensis* suggests that this species was broadly distributed along the southern margin of Wisconsin ice permitting wider dispersal after the ice receded. Refugia in northwestern North America are known to have been restricted to a few smaller areas around the Beaufort Sea. Future work on the genetic variation of copepods could be very useful in establishing the probable dispersal routes across the arctic region by these organisms. Species studied in the region of their glacial refugium should be expected to contain higher levels of the genetic variability than populations, which may have been established from a few individuals, outside the refuge.

Acknowledgments

Financial support for this project came in part from NSERC operating grant to P.H. and a DINA Northern Scientific Training Grant to M.B. Support at Inuvik from the Western Arctic Scientific Resource Centre of the Department of Indian Affairs and Northern Development was greatly appreciated.

References

Avise, J.C. 1975. Systematic value of electrophoretic data. Systematic Zoology 23:465–481.

Ayala, F.J. 1983. Enzymes as taxonomic characters. In: G.S. Oxford and D. Rollinson eds. Protein Polymorphism: Adaptive and Taxonomic Significance. New York: Academic Press 3–26.

Ayala, F.J., C.A. Murao, S. Perez-Salas, R. Richmond and T. Dobzhansky. 1970. Enzyme variability in the *Drosphila willistoni* group. I. Genetic differentiation among sibling species. National Academy of Sciences. U.S.A. Proceedings 67:225–232.

Ayala, F.J., and J.R. Powell. 1972. Allozymes as diagnostic characters of sibling species of *Drosophila*. National Academy of Sciences. U.S.A. Proceedings. 69:1094–1096.

Carl, G.C. 1940. The distribution of some Cladocera and free-living Copepoda in British Columbia. Ecological Monographs 10:56–110.

Dowling, T.E., and W.S. Moore. 1985. Genetic variation and divergence of the sibling pair of cyprinid fishes, *Notropis cornutus* and *N. chrysocephalus*. Biochemical Systematics and Ecology 13:471–476.

Hebert, P.D.N., and M. Beaton. 1986. Cellulose acetate gel electrophoresis. University of Windsor, Department of Biological Sciences, Windsor, Ontario.

Hebert, P.D.N., and J.M. Loaring. 1986. Systematics of the *Daphnia pulex* group: variation in an agamic complex and description of a species new to North America. Biochemical Systematics and Ecology. 14:333–340.

Hedgecock, D., M. Tracey and K. Nelson. 1982. Genetics. In: Bliss, D., ed. The Biology of Crustacea. Vol. 2. New York: Academic Press Inc. 283–403.

Hooper, F.F. 1947. Plankton collections from the Yukon and Mackenzie River systems. American Microscopial Society. Transactions. 66:74–84.

Kincaid, T. 1953. A contribution to the taxonomy and distribution of the American freshwater calanoid Crustacea. Seattle: The Calliostoma Company.

Manwell, C., and C.M.A. Baker. 1963. A sibling species of sea-cucumber discovered by starch gel electrophoresis. Comparative Biochemistry and Physiology 10:39–53.

Manwell, C., C.M. Baker, P.A. Ashton and E.D.S. Corner. 1967. Bochemical differences between *Calanus finmarchius* and *C. helgolandicus*. Marine Biological Association. U.K. Journal 47:145–169.

Marsh, C.D. 1915. A new crustacean, *Diaptomus virginiensis*, and a new description of *Diaptomus tyrelli* Poppe. U.S. National Museum. Proceedings. 49:457–462.

Marsh, C.D. 1918. Copepoda (Of North America). In: Ward, H.B., and Whipple, G.C. eds. Fresh Water Biology. New York: John Wiley & Sons. 741–789.

Marsh, C.D. 1920. Freshwater Copepoda. In: Report of the Canadian Arctic Expedition 1913-18. Vol. 7. Crustacea. Part J. Freshwater Copepoda. Ottawa: J. de Labroquerie Tache. 1–24.

Nei, M. 1972. Genetic distance between populations. American Naturalist 106:283–292.

Nei, M. 1975. Molecular Population Genetics and Evolution. New York: American Elsevier Publ. Co., Inc.

Nevo, E. 1978. Genetic variation in natural populations: patterns and theory. Theoretical Population Biology 13:121–177.

Pennak, R.W. 1953. Freshwater Invertebrates of the United States. New York: The Ronald Press Co.

Powell, J.R. 1975. Protein variation in natural populations of animals. In: T. Dobzhansky, M.K. Hecht and W.C. Steere eds. Evolutionary Biology. Vol. 8. New York: Plenum Press. 79–119.

Wilson, M.S. 1959. Calanoida. In: W.T. Edmondson ed. Freshwater Biology. 2nd Edition. New York: John Wiley & Sons. 738–794.

THE ARCTIC CHAR WINTER FISHERY OF KANGIQSUALUJJUAQ, QUEBEC

T. Boivin and G. Power

Department of Biology, University of Waterloo, Waterloo, Ontario N2L 3G1

Level: T. Boivin, Master's

Abstract

The arctic char (*Salvelinus alpinus*) is the most important fish species harvested by the Inuit of northern Quebec. The Kangiqsualujjuaq (George River) area of eastern Ungava Bay has the highest concentration of char-producing rivers, and many of these are utilized by the Inuit for subsistence and small-scale commercial purposes. Char are captured by local hunters throughout the year, but over one third of the community's catch is taken during the winter months. The winter fishery of the George River Inuit was studied from November, 1985 to April, 1986. The Inuit travel extensively by snowmobile, and more than 1750 km was covered visiting 7 winter fishing areas to sample local catches and observe the fishery. Over 200 hours of interviews with Inuit hunters provided information on fishing methods both past and present, locations of char systems, fishing effort, use of the catch and the importance of fishing in the winter lifestyle. The combination of questionnaire survey and field research was found to be a useful technique for monitoring a northern subsistence fishery.

Key words: Arctic char, subsistence fishery, fishing effort, Kangiqsualujjuaq, Ungava Bay, Quebec.

Résumé

L'omble arctique (*Salvelinus alpinus*) est l'espèce de poissons la plus largement pêchée par les Inuit du Nord québécois. La région de Kangiqsualujjuaq (rivière George), à l'Est de la baie d'Ungava, comprend la plus grande concentration de rivières où les ombles prolifèrent, et les Inuit les

pêchent pour leur consommation propre et la vente à petite échelle. Les chasseurs-pêcheurs locaux capturent des ombles tout au long de l'année, mais le tiers des prises sont capturées au cours de l'hiver.

Les auteurs ont étudié la pêche hivernale des Inuit de la rivière George de novembre 1985 à avril 1986. Les Inuit se déplacent beaucoup en motoneige, et les auteurs ont parcouru plus de 1 750 km pour visiter six lieux de pêche hivernale afin d'y échantillonner les prises et d'observer les activités de pêche. Plus de 200 heures d'entrevues avec des chasseurs-pêcheurs inuit leur ont fourni des renseignements sur les méthodes de pêche anciennes et actuelles, l'emplacement des pêcheries, l'activité de pêche, l'utilisation des prises et la place de la pêche dans le mode de vie hivernale. Les auteurs estiment que l'association d'un relevé par questionnaires et d'une enquête sur place constitue la meilleure méthode pour suivre les activités de pêche de subsistance dans le Nord.

Mots-clés: Omble arctique, pêche de subsistance, activités de pêche, Kangiqsualujjuaq, baie d'Ungava, Québec.

Introduction

The arctic char (*Salvelinus alpinus*) is the most important fish species to the natives of northern Canada (Balikci, 1980; Gillis *et al.*, 1980; J.B.N.Q.N.H.R.C., 1982; Power and Barton). In northern Quebec, it is second only to caribou in terms of edible weight in both the winter and yearly diet; char alone account for up to 60% of the total harvest of fish by edible weight (J.B.N.Q.N.H.R.C., 1982). Conservation of char populations is a top priority in northern Quebec communities. Information obtained from recent studies on the potential for increasing the abundance of char stocks (Barton *et al.*, 1984; Boivin *et al.*, 1985) is of great interest to native wildlife managers.

Char have been poorly studied relative to other salmonids, and except for some small areas in the Northwest Territories and Labrador, even basic information is lacking. Information on subsistence fisheries is also in short supply. Quantifying the substantial catches of native communities is a topic of increasing interest, especially since the Inuit population in northern Quebec is increasing at a current rate of 2.8% per year (Robitaille and Choniere, 1985). The increased demand of char as a subsistence food item and the probable future development of native-run commercial fisheries will require a significant data base from which management strategies may be designed.

Although harvest figures for large game and fur animals are believed to be reasonably accurate, data regarding fish yields have tended to be questionable (see Berkes, 1983 for discussion of this topic). Accurate methods for quantifying fish harvests are not well established, but their importance is obvious. Any research which discusses this topic is of value, both as a test of accuracy of existing records as well as a contribution to a data base with which future studies may be compared. At the very least insight may be obtained regarding management of northern resources.

Under the James Bay and Northern Quebec Agreement (1975), the Inuit received exclusive hunting and fishing rights over their territories. Since traditional subsistence harvesting takes place over a wide geographical area and hunting trips may last several days, it is difficult to monitor total fishing effort without actually participating in fishing activities. However, it is physically (and economically) impossible to follow every hunter in the field. Thus, some sort of questionnaire or diary must be incorporated in any study to account for activities which take place when the researcher is not present. Combining a field study approach with a questionnaire allows the researcher to check the reliability of data as it becomes available (Berkes, 1983).

Few studies have attempted to quantify native fish harvests in Canada. In northern Quebec, fisheries research has been centered around the James Bay area (Power, 1979). The J.B.N.Q.N.H.R.C. (1982) study in northern Quebec included little or no fieldwork outside the communities monitored. While fairly accurate harvest numbers were obtained from the study, the exact locations of catches was not included in the census. When fieldwork is incorporated in native harvest research (Berkes, 1977, 1979, 1983) it focuses primarily on summer effort. For Inuit communities, which can harvest up to 42% of their total char catches in winter, this results in a major gap in the data base.

This study was designed to help bridge some of the data gaps and to provide essential documentation of the winter fishery, which can last up to seven months. Winter is a difficult time to sample fish catches as temperatures can drop below −40°C. However, numerous benefits can accrue from such studies. The life cycle of the arctic char lends itself to a winter study, since these fish are confined to freshwater systems during this period. The Inuit winter fishery takes advantage of these concentrations (Sprules, 1952). Further winter harvests are presumed to be from the same stock (Johnson, 1980) unlike summer catches which probably include individuals from different populations. The George River (Kangiqsualujjuaq) area of eastern Ungava Bay (Fig. 1) has the highest concentration of char-producing rivers, many of which are utilized by the Inuit for subsistence and small scale commercial purposes. Travel by snowmobile is much easier and faster than canoe travel in summer, and many fishing areas are only accessible at this time. With improved fishing technology, especially in the last few years, char are now easier to catch than ever before. Since young people are confined to schools in winter, it is also the best time to follow the experienced full-time hunters when they undertake their traditional hunting activities. Lastly, hunters have ample spare time to chat and answer questions in winter, especially when the weather is bad. Anyone who has tried to undertake questionnaire surveys or community-based research in the summer knows the problems associated with trying to locate informants when many of the residents may be at summer camps. These problems are reduced by researching in the winter.

This paper will focus on the winter fishery near the village of Kangiqsualujjuaq, northern Quebec. It describes the methods used to study subsistence fisheries and a discussion of fishing effort, which together provide a unique analysis of the native fishery.

Methods

From 20 November, 1985 to 15 April, 1986, I resided in the Inuit community of Kangiqsualujjuaq in Ungava Bay (population 400). Before any fieldwork began, meetings with members of Anguvigaq (native wildlife committee) and the

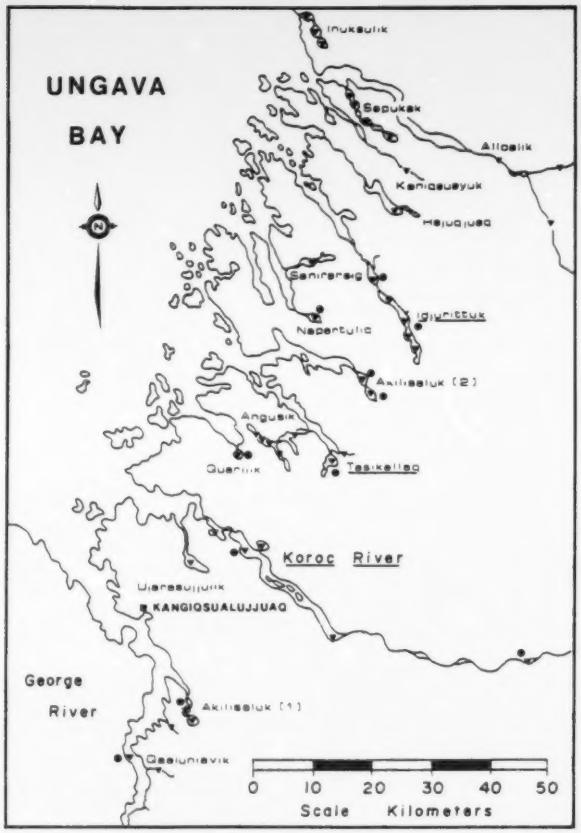


Figure 1. Arctic char systems located near the community of Kangiqsualujjuaq and sampling sites in the study of the winter fishery, 1985-1986.
▲ = arctic char rivers, lakes, overwintering and spawning sites;
● = sampling sites in the winter fishery study;
⊙ = hunter's catches from these locations were sampled in the community.

landholding corporation were organized to discuss the purpose of the study and to receive local consent. Broadcasts over the local F.M. station helped to notify members of the community about the study, and to help locate informants.

The researchers travelled over 1750 km by snowmobile to 7 different fishing locations utilized by the hunters. At each location, hunter's fishing sites were visited to record each net length, water depth at which nets were set, the methodology used, and the length of time nets were in the water. When nets were checked by hunters, I weighed and measured all the fish caught in that net set (defined as the length of time between setting and checking a gillnet). Other hunting activities pursued by the hunters were recorded.

Biological data collected included weight (±25 g), fork length (±0.5 cm), sex, and otolith and visceral samples from a stratified sample of catches.

In the community, over 125 hours of 'short' interviews (a half hour each) were undertaken with hunters who had just returned from fishing and hunting activities. Information regarding fishing locations visited, fishing effort, and numbers of char caught per net set was collected in this manner. Hunters were visited in their homes at least once a week, and usually the day after they returned from camping to question their fishing activities. Hunter's personal catches (those fish kept for family consumption) were weighed and measured in their equipment shacks or homes. Those fish which were sold to the local cooperative store were weighed and measured in the store itself, and records were kept of total coop purchases.

Another 75 hours of 'intensive' interviews with 40 hunters (including full-time, part-time and younger hunters) were undertaken to obtain background information regarding fishing locations, locations of char systems, methods and equipment utilized (past and present), utilization of the catch, species preferences and hunting activities. Direct observation of the fishery, combined with the questionnaire format, was found to be the best method for checking the validity of reported harvest levels.

Winter fishing methods

Today the Inuit use three main methods for capturing arctic char in winter: nets (usually multi-filament, but occasionally monofilament gillnets of stretched measure 8–15 cm), fishing spears (kakivak or leister), and jigging. Of the three, nets are the most effective. Kakivak is the most traditional method and is used mainly by men (for details of kakivak usage, see Balikci, 1964). Jigging, an activity mainly undertaken by women, is also very productive for the experienced hunter (I witnessed one woman catch 5 small char of mean weight 1550 g in about 10 minutes).

The method for setting nets beneath the ice is quite interesting and relatively simple. Before a net is set, it is stretched out to remove collected debris and to measure the required distance for the guideline. Rope guidelines are set under ice with a wooden ice jigger which is inserted through an ice hole. The jigger is then moved along the undersurface of the ice, towing the guideline behind it. Once the jigger has moved the desired distance, its position is located, a hole is cut through the ice and the jigger is removed from the water. The floatline of the net is then tied to the guideline and the net is pulled into place beneath the ice. Nets were weighted with rocks and were allowed to sink to the bottom of the lake. They are usually set in water 10–15 m deep, but on one occasion I witnessed a hunter set his net as deep as 30 m. Wooden poles are tied to each end of the net so that the fishing location is easily discernible. With an ice jigger, a net can be set in less than half an hour.

Before ice jiggers arrived (about 5 years ago), the process of setting a net was more tedious. A series of holes had to be cut (compared to only two with an ice jigger), and the guideline passed between each hole, one at a time, using a long wooden pole (usually the largest tree one could find, with the branches removed). Depending on ice thickness, which can be greater than 3 m in late winter, length of pole used, and numbers of persons assisting, this could take more than two hours. When a hunter leaves a fishing area to return home, the guidelines are left under the ice and can be reused during the next fishing trip.

The winter fishery

The winter fishery of Kangiqsualujjuaq is directed mainly towards arctic char, but lake trout (*Salvelinus namaycush*), brook trout (*Salvelinus fontinalis*), whitefish (*Coregonus clupeaformis*) and Atlantic salmon (*Salmo salar*) are also captured. Since the four latter species constituted less than 10% of the total catches sampled and reported, this discussion will deal solely with the char harvest.

Figure 1 shows the char systems located near the community, the most important fishing areas, and locations of sampling sites used in the 1985-1986 winter fishery study. From the time the community of Kangiqsualujjuaq was formed in 1959 to the late 1970's, winter fishing effort concentrated on two systems: Tasikallaq and the Koroc River. Although these two areas still experience the majority of effort today, fishing pressure has been more dispersed in recent years. Inuit population increases and the possibility of commercial operations have resulted in a local desire to conserve these two areas for subsistence use only. As a result Idjurittuk and Napartuliq have experienced an increase in effort, as well as Akilisaluk (A), Akilisaluk (B) and the George River (Qaaluniavik). Very little or no effort has been exerted upon Quarliik, Ujarasujjulik, Angusik, or systems further north. The winter of 1985-86 saw the first effort expended upon Akilisaluk (A) and Akilisaluk (B) in over 20 years, and fishing took place at Qaaluniavik for the second winter (the first was 1983-84) in over 5 years. Catches of char were very high at Qaaluniavik, and this was also the only area to record whitefish harvests. The lone Atlantic salmon sampled also originated here. Since catches at the newly-explored areas were relatively high this year, one might expect intensification of fishing effort in these areas in the future.

A seasonal cycle of fishing effort during winter is quite evident. In late November, when the ice is first suitable for snowmobile travel, the Koroc River is the only accessible char system and it is fished very intensively. By early December, weather permitting, the trail is safe for travel to Tasikallaq. These two areas receive the majority of the early winter effort. After Christmas, effort at the Koroc River declines drastically, but Tasikallaq remains important for the entire winter. By late January, all areas are accessible by snowmobile, and effort begins to disperse to other char systems. As the quality of the trail decreases by late winter, so does the accessibility of these distant systems. By late April or early May, the Koroc River is again the only accessible fishing site.

It is important to note the activities which take place during a 'typical' hunting trip, since this helps determine the actual amount of time spent fishing relative to other activities. Travelling distance to fishing sites ranged from 30 minutes (to Koroc River or Akilisaluk (A)) to five hours (Napartuliq or Idjurittuk). Upon arrival, canvas tents are set up and firewood gathered before work on setting nets begins. Often one must wait until the next day to set nets, especially in early winter when the number of daylight hours is limited. Once a net is set, the hunter need only check it twice a day (or more often if food is needed for camp). This provides opportunities for pursuing other activities. Fox trapping, ptarmigan, caribou, wolf or polar bear hunting, jigging, fishing with kakivak, collecting mussels and socializing with the other hunters are all activities which are enjoyed at the camping site.

The importance of the ice jigger both to northern fisheries and to hunting activities cannot be overlooked. Nets are set much more quickly now than in the past, so the hunter has more time to pursue other activities. This has resulted in more efficient harvesting of fish and, indirectly, that of game.

Catch data and fishing effort

Table 1 shows the total numbers of char captured by a sample of 20 hunters in the winter fishery study. The data from November and December represent the catch of 15 hunters, and from January to April 20 hunters. A total of 3554 char were captured by gillnet. All of the early winter catch comes from the Koroc River. Catches after Christmas at this site are very low, but increase once again as spring approaches.

TABLE 1
Total numbers of arctic char captured by a sample of 20 hunters from Kangiqsualujjuaq during the 1985-1986 winter fishery

Location	Nov. 85[1]	Dec. 85[1]	Jan. 86	Feb. 86	Mar. 86	Apr. 86	Totals
Koroc River	572	144	16	11	2	34	779
	(100)	(12.3)	(4.6)	(2.2)	(0.3)	(10.3)	(21.9)
Tasikallaq	0	1026	281	125	33	76	1541
		(87.7)	(80.1)	(24.8)	(5.3)	(23.0)	(43.4)
Idjurittuk	0	0	32	119	143	91	385
			(9.1)	(23.7)	(22.8)	(27.6)	(10.8)
Akilisaluk (A)	0	0	22	34	0	0	56
			(6.2)	(6.8)			(1.6)
Napartuliq	0	0	0	75	119	114	308
				(14.9)	(19.0)	(34.5)	(8.7)
Qaaluniavik	0	0	0	139	111	0	250
				(27.6)	(17.6)		(7.0)
Akilisaluk (B)	0	0	0	0	220	15	235
					(35.0)	(4.6)	(6.6)
Totals	572	1170	351	503	628	330	3554

Numbers in brackets indicate percentage (%) contribution of catches to the column totals.
[1]Only 15 hunters sampled at these times.

TABLE 2
Distribution of fishing effort by 20 hunters from Kangiqsualujjuaq during the winter of 1985-1986 expressed in numbers of net sets

Location	Nov. 85	Dec. 85	Jan. 86	Feb. 86	Mar. 86	Apr. 86	Totals
Koroc River	50	18	5	2	1	6	82
	(11)	(1)	(0)	(2)	(0)	(2)	(16)
Tasikallaq	0	59	31	29	7	12	138
		(10)	(18)	(8)	(0)	(2)	(38)
Idjurittuk	0	0	6	24	20	7	57
			(0)	(0)	(17)	(0)	(17)
Akilisaluk (A)	0	0	3	8	0	0	11
			(0)	(2)			(2)
Napartuliq	0	0	0	25	23	13	61
				(2)	(0)	(0)	(2)
Qaaluniavik	0	0	0	8	5	0	13
				(0)	(1)		(1)
Akilisaluk (B)	0	0	0	0	26	2	28
					(25)	(0)	(25)
Totals	50	77	45	96	82	40	390
	(11)	(11)	(18)	(14)	(43)	(4)	(101)

Numbers in brackets indicate numbers of net sets examined in the field.

Most fish were captured from Tasikallaq; 67% of the 1541 fish harvested here came in the month of December. Tasikallaq effort is at its peak at this time, and it is the only system to receive fairly constant fishing pressure throughout the winter. Idjurittuk, Napartuliq, and Qaaluniavik contributed 10.8, 8.7, and 7.0% of the total catch respectively, and are thus growing in importance as important fishing sites. Akilisaluk (B), which only received effort in March and April, accounted for 6.6% of the total catch. It is almost certain that this 'new' char system will receive increased fishing pressure in the future as the high catch per unit of effort (cpue) is discussed in the community. Akilisaluk (A) contributed 1.6% of the total catch, not a substantial amount, but its close proximity to town lends itself to future intensification of effort.

Of the 20 hunters sampled, 15, 13 and seven accounted for the fishing effort at Tasikallaq, Koroc River and Idjurittuk respectively; four hunters were responsible for all catches from Napartuliq. Effort at Akilisaluk (B) was undertaken by two hunters, while three hunters fished at Qaaluniavik and Akilisaluk (A).

Another point worth mentioning is the fact that fishing effort is directly proportional to the amount of char that the local coop wishes to purchase for sale. Evidence to support this statement is the obvious decline of effort in early February, when no fish purchases were made, compared to a period of intense effort in mid-December when the coop purchased a large amount of char. When the coop wants to sell char, they broadcast their wishes over the local F.M. station, and soon after hunters are planning their next fishing trip. Whether this desire to catch fish for commercial sale will continue in the future remains to be seen.

Berkes (1977) showed that catch per net set is an appropriate measure of cpue since there appears to be no correlation between length of time a gillnet is set in the water and the total catch. This approach to cpue analysis will be used in this study. Table 2 shows the total number of net sets over time for each location used by the 20 hunters. It is clear from this data that effort at Tasikallaq is the highest for all locations followed by Koroc River. Napartuliq and Idjurittuk experience relatively the same effort, despite the fact that Idjurittuk was visited by more hunters. In March, Akilisaluk (B) was the site of more effort than that seen at Koroc River and Tasikallaq combined. Akilisaluk (A) and Qaaluniavik received the least effort in terms of number of net sets, but catches at the latter were much greater than the former. In fact, overall cpue at Akilisaluk (A) was very low.

Catch per net set is certainly the best indicator of fishing effort for this type of study. If numbers of net days (defined as setting a gillnet for one 24-hour period) is used as an index of fishing effort (Table 3), quite contrasting results are obtained for some systems. Tasikallaq and Koroc River are still shown to be the areas with the highest effort, but Akilisaluk (A) is overemphasized in importance while the influence of Akilisaluk (B) is not as apparent. In reality, Akilisaluk (A) experienced little overall effort, as nets were set for long periods of time (up to six days) before checks were made. The close proximity of this system to the community results in fishermen setting nets, returning home and then checking them every few days or so. This practice was rare however, contrary to what appears to be the case for winter ice fishing in lakes by Cree (Berkes, 1979). The overall low catches from this system support the theory that catches are not correlated with time nets are set in the water, and that catch per net set is a better index for the fishing success in a subsistence fishery.

Conclusions

From this brief summary of fish catches and effort, it is clear that while Tasikallaq and Koroc River experience the majority of fishing pressure by the community, other fishing areas are emerging as important contributors to the total harvest.

TABLE 3
Distribution of fishing effort by 20 hunters from Kangiqsualujjuaq during the winter of 1985-1986 expressed in numbers of net days

Location	Nov. 85	Dec. 85	Jan. 86	Feb. 86	Mar. 86	Apr. 86	Totals
Koroc River	33	12	3	1	1	3	53
Tasikallaq	0	37	17	18	4	8	84
Idjurittuk	0	0	4	12	12	4	32
Akilisaluk (A)	0	0	11	18	0	0	29
Napartuliq	0	0	0	13	19	6	38
Qaaluniavik	0	0	0	11	5	1	17
Akilisaluk (B)	0	0	0	0	15	1	16
Totals	33	49	35	73	56	23	269

The combination of fieldwork and questionnaire survey in the study of native fisheries is important for obtaining the widest possible range of information. There are many cultural, social, and economic factors involved in overall fishing effort, and each of these must be understood before any management strategies may be formulated. A questionnaire survey alone does not give the researcher the opportunity of checking the reliability of his data. A field study alone undoubtedly will tend to concentrate on the biological aspects of the fishery, and would miss some of the most important factors which regulate fishing intensity. Integrating these two approaches helps one to obtain an overall picture of the complexity of activities taking place in a subsistence fishery (Berkes, 1983).

The usual questions that stem from such research include: What is overall fishing pressure? Will the resource base be able to sustain such activity? Are the Inuit overfishing or are they carefully managing their resources? Should commercial fishing operations be allowed? These questions are difficult to answer, especially when only one winter's fishing was analyzed in this study. However, some insight may be presented.

Awareness to conserve key fishing areas for subsistence use, and the extension of fishing effort to different areas is a positive indicator that the Inuit of Kangiqsualujjuaq are taking the proper steps towards controlling their own fishing activities. However, rapid population growth in the region and the very real possibility of char commercialization may elevate fishing pressure to a point where it is difficult to control without stricter regulation.

Although subsistence fishing pressure in the past has had a minimal effect on char resources (Dunbar and Hildebrand, 1952), commercial operations undertaken in the Ungava Bay district have failed mainly because the resource could not sustain such intensive pressure (Power and LeJeune, 1976). The combination of both fisheries could have a devastating effect on this important food item, to the extent that it may be years before the population can return to harvestable levels. Commercial char fisheries in northern Labrador, however, have managed to sustain high yields without drastically affecting the subsistence harvest (Le Drew, 1984).

One option that seems to be available, if the community decides to embark on commercial fishing, is to diversify effort even more to include accessible systems not currently being fished. There is of course a limit to such expansion and it can only be done at a cost. Increased travel time and fuel costs must be weighed against the potential returns. Assuming that char systems are relatively discrete and there is little exchange between areas, there is also the risk of increasing present costs and effort to maintain the subsistence catches unless nearby areas are reserved for domestic use. Biological evidence suggests this is so, but it remains to be confirmed in the Ungava area.

Inuit would like to have more control over their own actions in the North. The decision whether or not to expand fishing pressure in the form of commercial operations generally comes from government agencies in the South. Without a reliable data base from which to make these important decisions, there is the distinct possibility that judgements will be made based on incomplete information. By integrating biological information about char, the vast Inuit knowledge about the species passed down from their ancestors, and past experience with commercial fishing operations, sound decisions can be formulated for future management of the species.

Obviously decisions have to be made, many before all the evidence is in. It is hoped that the Inuit are able to make the right ones and they are not driven too quickly by the potential job creation and monetary rewards of commercialization.

Acknowledgments

Numerous persons were extremely helpful to the authors throughout the course of the study. I would like to thank the residents of Kangiqsualujjuaq for their assistance and cooperation during my stay in their community. The hospitality that Bobby Baron and family showed the researchers was much appreciated. Simeonie Baron provided invaluable field assistance, and his knowledge of the land and hunting skills were one of the key factors in our overall success. The Department of Fisheries and Oceans provided research funds administered by Makivik Corporation. Additional funding was provided by a NSERC grant to G. Power. T. Boivin received a Studentship from the Association of Canadian Universities for Northern Studies.

References

Balikci, A. 1964. The Netsilik Eskimo. The Natural History Press, New York. 264 p.

Balikci, A. 1980. Char fishing among the Arviliqjuarmiut, 7-9. In: Balon, E.K., ed., Charrs: salmonid fishes of the genus *Salvelinus*. The Hague, Junk. 928 p.

Barton, D., T. Boivin, B. de Schiffart, M. Lefevre, Peter Lemieux, and G. Power. 1985. A feasibility study of the potential for increasing the abundance of anadromous arctic char (*Salvelinus alpinus*) in northern Quebec. Parts 1-4. Makivik Corporation Research Department, Montreal, Quebec.

Berkes, F. 1977. Fishery resource use in a subarctic Indian community. Human Ecology, 5:289–307.

Berkes, F. 1979. An investigation of the Cree domestic fisheries in northern Quebec. Arctic, 32:46–70.

Berkes, F. 1983. Quantifying the harvest of native subsistence fisheries. In: Resources and dynamics of the boreal zone. R.W. Wein *et al.*, editors. ACUNS. Ottawa.

Boivin, T., G. Power and D. Barton. 1985. A feasibility study of the potential for increasing the abundance of anadromous arctic char (*Salvelinus alpinus*) in northern Quebec. Part 5: Report to communities and Inuit evaluation of results. Makivik Corporation Research Department, Montreal, Quebec. 11 p.

Dunbar, M.J. and H.H. Hildebrand. 1952. Contribution to the fishes of Ungava Bay. Journal of the Fisheries Research Board of Canada. 9:83–128.

Gillis, D.J., M. Allard and W.B. Kemp. 1982. Life history and present status of anadromous arctic char (*Salvelinus alpinus*) in northern Quebec with case studies on the George, Payne and Kovik rivers. Kativik Regional Government Inuit Hunting, Fishing and Trapping Support Program. 107 p.

James Bay and Northern Quebec Agreement. 1975. Editeur officiel de Québec.

James Bay and Northern Quebec Native Harvest Research Committee. 1982. Research to establish present levels of native harvesting. Harvests by the Inuit of northern Quebec. Phase II (yr. 1979 and 1980). Montreal.

Johnson, L. 1980. The arctic char, *Salvelinus alpinus*, 15–98. In: Balon, E.K., ed., Charrs, salmonid fishes of the genus *Salvelinus*. The Hague, Junk. 928 p.

Le Drew, L.J. 1984. Historical development of the arctic charr fishery in northern Labrador, p. 537–548. In: L. Johnson and B.L. Burns, eds. Biology of the arctic charr, Proceedings of the international symposium on arctic char, Winnipeg, Manitoba Press, Winnipeg.

Power, G. 1979. Problems of fisheries management in northern Quebec. Fisheries Management 10, No. 3. Great Britain.

Power, G. and R. Le Jeune. 1976. Le potentiel de pêche du Nouveau Québec. Cahiers de Géographie de Québec. 20(50):409–428.

Power, G. and D. Barton. Factors affecting anadromous arctic char (*Salvelinus alpinus*) stocks in Ungava Bay. Manuscript submitted to Arctic.

Robitaille, M. and R. Choniere. 1985. An overview of demographic and socio-economic conditions of the Inuit in Canada. Research Branch Corporate Policy, Indian and Northern Affairs, Canada. 112 p.

Sprules, W.M. 1952. The arctic char of the west coast of Hudson Bay. Journal of the Fisheries Research Board of Canada. 9(1):1–15.

SOME IMPLICATIONS OF HYDROELECTRIC DEVELOPMENT AND RELATED ENGINEERING PROJECTS IN NORTHERN CANADA

Allan R. Chapman

Watershed Ecosystems Program, Trent University, Peterborough, Ontario K9J 7B8

Level: Master's

Abstract

While economic gains associated with the damming and diversion of northern Canadian rivers have generally benefited Canada as a whole, there are many consequences detrimental to northern environments and people. This paper briefly surveys the major river engineering projects that have been completed in, or planned for, the Canadian north, and describes some of the associated ecological and social effects.

Completed in 1976, the Southern Indian Lake impoundment and Churchill River diversion project diverts 75% (760 $m^3 \cdot s^{-1}$) of the Churchill River flow southward across the natural drainage divide, along 300 km of tributary valleys, and into the Nelson River channel, where a 10,000 MW hydroelectric scheme is being developed. Environmental changes associated with the project include: severe erosion of glacial clay shorelines, which previously existed in permafrost; reduced light penetration in flooded lakes; collapse of the whitefish fishery in Southern Indian Lake; and, increases in fish mercury levels in flooded lakes. Many of the major environmental effects of flooding and diversion were either poorly predicted or completely unpredicted, despite extensive pre-development studies. Associated with the environmental effects were severe socio-economic repercussions for communities along the diversion route.

The GRAND Canal Concept, an old proposal which has gained recent support, would turn James Bay into a freshwater lake and divert the water southward. This project, the largest yet proposed for any northern country, has the potential for unpredictable environmental disruption of an unprecedented magnitude. Immediately affected would be 10,000 Inuit living along James Bay, and another 22,000 treaty Indians in northern Ontario.

As a matter of national policy, Canadian economic growth must be tempered with an understanding and concern for northern Canadian ecosystems and people.

Key words: Hydrology, river diversion, subarctic, Southern Indian Lake, Grand Canal Concept.

Résumé

Bien que la construction de barrages sur les fleuves du Nord du Canada et leur détournement aient en général été profitables pour l'économie du pays, de nombreux inconvénients ont frappé le milieu nordique et les Nord-Canadiens. L'auteur passe rapidement en revue les grands aménagements hydroélectriques réalisés ou en projet dans le Nord canadien, et décrit certaines de leurs conséquences écologiques et sociales.

Le captage des eaux du lac Southern Indian et le détournement du fleuve Churchill, achevés en 1976, permettent d'acheminer 75 % (soit 760 $m^3 \cdot s^{-1}$) des eaux du Churchill vers le sud, au travers de la ligne de partage des eaux, par 300 km de vallées d'affluents jusqu'au lit du fleuve Nelson, où l'on construit une centrale hydroélectrique de 10 GW. Les conséquences environnementales de cet aménagement sont, entre autres: une grave érosion des rives d'argile glaciaire, protégées jusque-là par le pergélisol; une réduction de la pénétration de la lumière dans les eaux lacustres; la destruction des pêcheries de corégones du lac Southern Indian, et l'augmentation de l'ingestion de mercure par les poissons des lacs submergés. La plupart des sérieuses conséquences écologiques de cette submersion et du détournement n'ont pas été prévues, ou tout au moins bien peu,

en dépit des vastes études entreprises avant l'aménagement. Parallèlement aux fâcheux effets sur le milieu, les collectivités humaines établies le long du fleuve détourné ont souffert de graves conséquences socio-économiques.

Le Projet de Grand Canal, une idée ancienne qui a retrouvé des partisans, permettrait de transformer la baie de James en un lac d'eau douce, dont les eaux seraient acheminées vers le sud. La réalisation de ce projet, le plus audacieux proposé jusqu'ici pour un pays nordique, pourrait provoquer un bouleversement du milieu naturel d'une ampleur sans précédent. Dix mille Inuit vivant autour de la baie de James et 22 000 Indiens du Nord de l'Ontario, protégés par les traités, seraient affectés par sa réalisation.

Il faut, dans le cadre de la politique nationale, modérer les désirs de croissance économique afin de protéger les écosystèmes du Nord et le bien-être de ses habitants.

Mots-clés: Hydrologie, détournement des eaux, subarctique, lac Southern Indian, Projet de Grand Canal.

Introduction

Water in rivers and lakes, as a result of being held above the base level of the oceans, possesses potential energy. Gradually, as the water moves downslope under the influence of gravity, the energy is lost; part is dissipated as heat generated by friction between the water and the land surface, while part is used by streams to do work such as eroding and transporting material. Long ago people learned that they could tap the potential energy of the moving water and use it to do work of their own design. Simple devices such as overshot water wheels, which convert potential energy into mechanical energy, have been used for a variety of purposes for many centuries (Petts, 1984). Today, the same technological principles still apply; water is impounded behind dams and used to turn wheels. In the modern case, though, the wheels are turbines and the energy conversion is usually to electrical. The major change from three hundred years ago to the present has been one of scale. Modern engineering efforts to tap the energy potential of moving water have been immense, involving large-scale manipulation of riverine and lacustrine environments, and often including the rerouting of water over many hundreds of kilometres to augment the discharge through hydroelectric turbines. Many of these projects, especially those which have been completed in northern regions, have had severe environmental and social repercussions (Baxter and Glaude, 1980). This paper briefly surveys the river engineering projects that have been completed in, or planned for, the Canadian north, and describes some of the associated ecological and social effects. The Southern Indian Lake impoundment and Churchill River diversion, completed in subarctic Manitoba in 1976, and the GRAND Canal Concept, a river diversion scheme proposed for the James Bay region, are discussed in greater detail. Southern Indian Lake and Churchill River diversion research, completed predominantly by scientists of the Freshwater Institute, Department of Fisheries and Oceans, provides some of the most valuable information available on impacts of major river engineering projects in northern regions. The GRAND Canal Concept is discussed since it seems to have found political support at both national and provincial (Quebec) levels.

River Engineering in Canada

Anthropogenic manipulation of rivers, usually for hydroelectric generation, has been common in Canada. Almost 70 percent of our electrical energy (Day, 1985), involving close to 400 impoundments on more than 200 rivers and streams (Efford, 1975), is generated by falling water. Hydroelectric development was first implemented on southern rivers, close to population and industrial centres. Over two-thirds of these projects were "run of the river" types, where the extent of environmental manipulation was limited by the interests of other water users (Newbury, 1981). As the hydroelectric potential of southern rivers began to be depleted, and as planners perceived an increasing need for energy, engineers turned to the north. Since 1970 three enormous hydroelectric projects have been completed in the Canadian subarctic. The Churchill Falls project in Labrador was completed in 1974 at a cost of $665 million; the Churchill-Nelson River diversion in Manitoba was completed in 1977 at a cost of $1.36 billion; while phase 1 of the La Grande project in Quebec was scheduled to be completed in 1985 at a cost of $14.6 billion (Day, 1985). These northern projects differ from those previously developed in three important ways (Newbury, 1981):

1. Competing uses and riparian interests are limited. River systems are thus engineered to maximize energy production. This has included the diversion of water from adjacent drainage basins to augment the flow of water over the turbines. The three hydroelectric projects mentioned above incorporated 5 diversions totalling 2886 $m^3 s^{-1}$. If concentrated into a single channel, it would create the fourth largest river in Canada, behind the St. Lawrence, Mackenzie and Fraser.
2. The projects are usually planned for a single purpose, frequently excluding traditional hunting, trapping and transportation uses of the river systems by native peoples.
3. Hydroelectric experience gained in southern Canada is not readily transferable to northern regions. Because of their immense size, the complexity of combining river systems, and the severe climatic conditions within which they operate, many of the design solutions and engineering practices applied to northern rivers are experimental. As an example, the Southern Indian Lake impoundment, as part of the Churchill-Nelson River project, was the first of its type in the widespread permafrost zone of North America. There had been no test impoundments in permafrost prior to the completion of the project, which resulted in massive erosion of clay shorelines, destructively altering the lacustrine environment of Southern Indian Lake.

In these large northern projects, drainage patterns can be completely altered by redirecting water over hundreds of kilometres, river valleys can be totally obliterated as diverted water flows through them, and the needs of northern peoples living traditional lifestyles along the waterways are frequently disregarded. To date, river engineering in northern Canada has been environmentally destructive on a large scale, and incompatible with the stable existence of northern peoples. This will be discussed further in the following section on the Southern Indian Lake impoundment and Churchill River diversion, part of a scheme to augment the hydroelectric potential of the Nelson River in subarctic Manitoba.

Figure 1. The Churchill and Nelson Rivers hydroelectric development, northern Manitoba. (From Bodaly *et al.*, 1984a)

The Southern Indian Lake impoundment and Churchill River diversion

The 250,000 km^2 Churchill River basin drains much of the northern portions of Alberta, Saskatchewan and Manitoba, ultimately discharging a mean annual flow of 1010 m^3 s^{-1} into Hudson Bay at the port of Churchill. It flows through Southern Indian Lake, a large (1977 km^2) multibasin lake. In 1976, a control structure at Missi Falls, the natural outlet of the lake, was closed, raising the water level of Southern Indian Lake by 3 m and forcing the Churchill River to discharge through a channel constructed at the south end of the lake (Fig. 1). About 75% (760 m^3 s^{-1}) of the Churchill River is now diverted through Southern Indian Lake, flooding the Rat and Burntwood River valleys (both of which had pre-diversion mean annual discharges of less than 100 m^3 s^{-1}), and into the Nelson River, where it is used to augment hydroelectric generation (Newbury et al., 1984).

The impoundment and diversion had profound effects on riverine and lacustrine ecosystems, including:

1. Halving of pre-diversion lake areas along the abandoned lower Churchill River, downstream of the Missi Falls control (Bodaly *et al.*, 1984a);
2. Increasing the area of Southern Indian Lake by 21% to 2391 km^2 (McCullough, 1981);
3. Flooding of 409 km^2 of land in the Rat River valley to create the Notigi Reservoir (Bodaly *et al.*, 1984a);
4. Flooding of lakes along the Burntwood River by 3–5 m to increase diversion flows (Bodaly *et al.* 1984a);
5. Severe erosion of shorelines along Southern Indian Lake as the water level rose from stable bedrock and flooded onto predominantly fine-grained frozen overburden (Newbury and McCullough, 1984), increasing the turbidity and decreasing the light penetration in the lake (Hecky, 1984; Hecky and McCullough, 1984). Shoreline erosion along the Rat and Burntwood River valleys was minimal, despite similar glacial clay deposits, because of the comparatively short wind fetches (Bodaly *et al.* 1984a);
6. Increased fish mercury levels in Southern Indian Lake and lakes in the Rat and Burntwood River valleys, likely due to the mobilization and methylation of natural soil mercury (Bodaly *et al.*, 1984b). Fish mercury levels appeared to vary directly with the severity of flooding, and had not declined 5 years after impoundment (Bodaly *et al.*, 1984b);
7. The commercial whitefish fishery on Southern Indian Lake collapsed soon after impoundment. The grade of catch declined immediately following impoundment from an export quality whitefish, lightly parasitized with muscle cysts, to a predominantly continental quality fish with higher rates of cyst infestation (Bodaly *et al.*, 1984c). Southern Indian Lake supported northern Manitoba's largest commercial fishery, with a pre-impoundment mean annual whitefish catch of 333,500 kg. Catch per unit effort declined to about one-half pre-flooding levels following impoundment, although total catches remained near the pre-impoundment level until 1982 due to greatly increased effort. After 1982 the annual whitefish catch declined to about one-third of the pre-impoundment mean (Bodaly *et al.*, 1984c).

The widespread environmental disruption makes remedial measures impractical and uneconomic. Recovery of ecosystem quality and stabilization of many of the altered biological processes will depend upon restablization of the eroding shorelines. Stabilization times of at least 40 years (Bodaly *et al.*, 1984a), but probably considerably longer (R.W. Newbury, Freshwater Institute, pers. comm.) are predicted for Southern Indian Lake. Despite extensive pre-development studies, many of the major environmental effects of impoundment and river diversion were either poorly predicted or completely unpredicted in the Churchill-Nelson system (Bodaly *et al.*, 1984a). As stated above, and supported by the extensive Southern Indian Lake impoundment and Churchill River diversion research, experience from southern regions is not readily transferable to the north.

Associated with the environmental effects were severe socio-economic repercussions for communities along the impoundment and diversion route, many of which arose from the insensitive attitude of Manitoba Hydro and the provincial government towards the communities (Day, 1985). Those to be affected were never consulted nor informed fully of the potential impact of the project. There thus occurred a sudden and dramatic reduction in the potential of the affected people to maintain their economic base of commercial fishing. This resulted from the decline in fish quality and the increased effort required per unit catch, combined with the increased fish mercury level. Economic surveys revealed that cash flow per fishing enterprise decreased by 66%, from

$3362 to $1141, between 1976 and 1980 (Wagner, 1984). By 1980 the average fisherman on Southern Indian Lake could not meet his capital costs (Wagner, 1984). Manitoba Hydro stated that its responsibility was to repair or replace facilities directly affected by the impoundment and diversion, and that the Government of Manitoba was responsible for compensation for effects on fishing, trapping and transportation (Tritschler, 1979). This responsibility was not assumed by the province, and Manitoba Hydro was forced to attempt ad hoc settlements with the communities over the course of many years (Day, 1985). Compensation payments by Manitoba Hydro until December 1983 totalled $38.6 million, including the cost of resettlement for the community of South Indian Lake. Of the more than 1000 claims filed for damage, about 100 are oustanding; also, another 100 claims are waiting to be settled by arbitration (Day, 1985). In general, some of the expensive class action suits remain unresolved, although Manitoba Hydro recently made a $30 million offer to settle these claims in perpetuity (Day, 1985). Day (1980:50) concludes:

> "In effect, the concerns of the affected communities and the protracted and bitter negotiations among the Northern Flood Committee (composed of the affected communities), the Manitoba government, and Manitoba Hydro were the result of inadequate engineering and environmental knowledge and a development strategy which placed little importance on local inhabitants who would be negatively affected by the project. Indeed, the Northern Flood Agreement was not achieved until the diversion was operational and it appears that the resolution of most induced problems will take more than a decade."

This discussion only touches on the socio-economic effects of river impoundment and diversion in northern Manitoba. There were many other more subtle effects related to the resettlement of people into new communities, the loss of livelihood, and the dramatic and widespread alteration of the northern environment. These include increased rates of alcoholism and inter-community violence, increased reliance on social welfare, and a general decline in the quality of a traditional way of life. In closing this section, it is somewhat ironic to note that in the economically based decision to proceed with the Southern Indian Lake impoundment and Churchill River diversion, which had many disastrous environmental and social impacts, there was no consideration of the possibility of compensation payments, almost as if the northern environment and people didn't exist; it appears that once compensation costs for resources lost due to the project are finalized, it would have been more cost effective to carry out independent development of hydroelectric potentials on the Churchill and Nelson Rivers, avoiding the impoundment of Southern Indian Lake and flooding of the Rat and Burntwood River valleys.

The GRAND Canal Concept

Like recurring nightmares, proposals calling for a major realignment of northern Canadian water keep appearing. Most of the proposals were developed during the 1930's and 1960's, when engineers seemed to be preoccupied with redesigning the North American continent, and most have been discarded as being economically unfeasible or politically undesirable. Projects such as the North American Water and Power Alliance (NAWAPA), which would divert water from rivers in British Columbia and Alaska to supply principally the southwestern United States, or the Western States Water Augmentation Concept, which would use the Liard River as a source, are well known and commonly used as examples of major diversion schemes (Sewell, 1983). Recently, however, another engineering proposal has received considerable attention. This is the Great Replenishment and Northern Lakes Development Canal (GRAND Canal Concept) of Thomas Kierans, a Newfoundland engineer. Quebec premier Robert Bourassa has advocated the proposal in his book *Power from the North*,, while Simon Reisman, Canada's free trade negotiator, has also offered support to the scheme.

Figure 2. The GRAND Canal Concept (from Kierans, 1985)

The GRAND Canal Concept proposes that 160 km of dikes be built to separate the major part of James Bay from Hudson Bay, converting James Bay from a marine ecosystem into a 70,000 km^2 freshwater reservoir (Fig. 2). About 2000 m^3 s^{-1} of water would then be diverted and pumped up the Harricanaw River valley through a series of eight stepped reservoirs, and over the natural divide separating the St. Lawrence drainage from the Hudson Bay drainage by way of an artificial canal. The diverted water would enter the Upper Ottawa River near Val d'Or, Quebec, and pass through Lake Kimiskaming into the Lower Ottawa. From there it would be transferred to the Ottawa River, near Mattawa, Ontario, into Lake Nipissing, and then via the French River into Lake Huron (Kierans, 1985). It is estimated that this 640 km diversion would require 10,000 MW of electrical power (Nikiforuk, 1986), more than the entire

Figure 3. Water distribution system for the GRAND Canal Concept (from Kierans, 1985)

output of the massive La Grande hydroelectric development project in northern Quebec. Once in the Great Lakes system, Kierans envisions using a system of canals, in combination with existing river valleys, to distribute the water to much of southern Canada and the continental United States (Fig. 3). Estimated total cost of the project is $100 billion, with proposed benefits of improved water management for the Great Lakes-St. Lawrence River system, and augmented water supplies for the arid regions of Canada and the United States (Kierans, 1985).

This paper avoids the important questions of whether the addition of James Bay water will improve regulation of the Great Lakes, or whether water from northern Canada is needed in the arid regions of North America. However, it is generally accepted that although local water shortages may exist in North America, specifically in the south-western United States, they arise from poor management, and can be reduced or eliminated by development of logical water-use policy rather than by engineering schemes (Bocking, 1972; Rogers, 1983).

Because an engineering project of this magnitude, involving profound manipulation of riverine, lacustrine and marine environments, has never been built, it is impossible to predict many of the associated environmental implications. Even comparatively smaller projects that had extensive pre-development studies, such as the Churchill-Nelson River project in northern Manitoba, resulted in many major environmental effects that were either poorly predicted or completely unpredicted (Bodaly *et al.*, 1984a). However, some of the major implications of the GRAND Canal on northern regions will include: 1. effects related to the dramatically altered hydrologic and hydraulic regimes, with associated biological effects, along the diversion route; 2. effects related to the conversion of James Bay into a 70,000 km freshwater reservoir, far larger than any lake presently found in the Canadian subarctic; and 3. effects related to the exclusion of water from the James Bay drainage basin from the marine ecosystem of Hudson Bay.

The proposed diversion of 2000 $m^3 s^{-1}$, creating the sixth largest river in Canada, would induce a major readjustment of the hydrologic and hydraulic regimes along the diversion route, since all of the rivers in the proposed route presently possess considerably lower discharges. The hydraulic geometry (depth, width, slope, meander wavelength, meander wave amplitude, etc.) of the affected waterways would begin to rapidly adjust to create a new stable form to carry the increased flow (Kellerhalls *et al.*, 1979). The potential energy added to the system by the extra water would be expended by doing work, ie. by eroding and transporting material, hydraulically destabilizing all the waterways affected. This destabilization is less easily predictable at a mesoscale, but it would be exhibited in dramatically increased rates of erosion and sediment load, and downstream deposition (including increased sedimentation in lakes along the system), which in turn would induce a myriad of associated biological effects. Restabilization of the riverine and lacustrine environments would take at least many decades, but probably much longer.

The conversion of James Bay from a marine ecosystem into a freshwater reservoir would have many dramatic, but probably unpredictable, effects; 70,000 km^2 of subarctic ocean has never been converted into a lake before. The reservoir would freeze earlier in the winter and thaw later in the spring than the unperturbed James Bay, possibly creating a number of climatological effects: the albedo would increase, evaporation would decrease and the net radiation input would decrease. These would likely have significant meteorological and ecological effects for a large area surrounding James Bay. The flora and fauna of James Bay would be completely altered, with a loss of marine forms and an increase in freshwater forms. However, as indicated by the Southern Indian Lake experience, the new reservoir would likely exhibit a reduction in fish productivity, lowering its potential for economic utilization by native peoples.

By diking James Bay and converting it into a lake, about 2000 $m^3 s^{-1}$ of freshwater is prevented from mixing with the saltwater of Hudson Bay, with a number of potential results. The salinity of Hudson Bay would likely increase, possibly affecting sea-ice formation and creating a longer open-water season. The average annual albedo would decrease, evaporation would increase, and net radiation input would increase. Interchange within and between the oceanographic and climatologic systems, and the impact of major river diversions on them, are complex and exceedingly difficult to model (Cattle, 1985). However, the repercussions would likely be large-scale, perhaps even global.

Socio-economic effects of the GRAND Canal project on peoples living in the James Bay region or along the diversion route would be extensive. The 10,000 native people living traditional lifestyles along the shores of James Bay

would have their livelihood virtually destroyed. Another 20,000–30,000 people living in northern Ontario and Quebec would also be severely affected.

The potential for both environmental and social destruction from this project are well beyond anything previously experienced in northern Canada, and Canada has a sad history of destructive interaction with its northern environment and people. As a matter of national policy, Canadian economic growth must be tempered with an understanding and concern for the inherent value of undisturbed northern environments, and for the traditional uses of that environment by native people and other northern residents.

Acknowledgments

The author is indebted to R.W. Newbury of the Freshwater Institute, Winnipeg, Manitoba, and to K.M. Sawatsky of Gibson's Landing, British Columbia.

References

Baxter, R.M., and P. Glaude. 1980. Environmental effects of dams and impoundments in Canada: experience and proposals. Canadian Bulletin of Fisheries and Aquatic Sciences, 205: 34 p.

Bocking, R.C. 1972. Canada's Water: For Sale? James Lewis and Samuel. Toronto.

Bodaly, R.A., D.M. Rosenberg, M.N. Gaboury, R.E. Hecky, R.W. Newbury, and K. Patalas. 1984a. Ecological Effects of Hydroelectric Development in Northern Manitoba, Canada: The Churchill-Nelson River Diversion. In: P.J. Sheehan, D.R. Miller, G.C. Butler and Ph. Bordeau, ed., Effects of Pollutants at the Ecosystem Level. SCOPE. John Wiley and Sons Ltd. pp. 273–309.

Bodaly, R.A., R.E. Hecky, and R.J.P. Fudge. 1984b. Increases in fish mercury levels in lakes flooded by the Churchill River diversion, northern Manitoba. Canadian Journal of Fisheries and Aquatic Sciences, 41: 682–691.

Bodaly, R.A., T.W.D. Johnson, R.J.P. Fudge, and J.W. Clayton. 1984c. Collapse of the lake whitefish (*Coregonus clupeaformis*) fishery in Southern Indian Lake, Manitoba, following lake impoundment and river diversion. Canadian Journal of Fisheries and Aquatic Sciences, 41: 692–700.

Cattle, H. 1985. Diverting Soviet rivers: some possible repercussions for the Arctic Ocean. Polar Record, 22: 485–498.

Day, J.C. 1985. Canadian Interbasin Diversions. Research Paper #6. Inquiry on Federal Water Policy, Government of Canada, Ottawa. 111 p.

Efford, I.E. 1975. Assessment of the impact of hydro-dams. Journal of the Fisheries Research Board of Canada, 32: 196–209.

Hecky, R.E. 1984. Thermal and optical characteristics of Southern Indian Lake before, during, and after impoundment and Churchill River diversion. Canadian Journal of Fisheries and Aquatic Sciences, 41: 579–590.

Hecky, R.E., and G.K. McCullough. 1984. Effect of impoundment and diversion on the sediment budget and nearshore sedimentation of Southern Indian Lake. Canadian Journal of Fisheries and Aquatic Sciences, 41: 567–578.

Kellerhalls, R.M., M. Church, and L.B. Davies. 1979. Morphological effects of interbasin river diversions. Canadian Journal of Civil Engineering, 6: 18–31.

Kierans, T.W. 1985. The Great Recycling and Northern Development (GRAND) Canal. In: Futures in Water. Proceedings, Ontario Water Resources Conference. Queen's Printer. Toronto. pp. 124–142.

McCullough, G.K. 1981. Water budgets for Southern Indian Lake, before and after impoundment and Churchill River diversion, 1972–1979. Canadian Manuscript Report of Fisheries and Aquatic Sciences, no. 1620: 22 p.

Newbury, R.W. 1981. Some principles of compatible hydroelectric design. Canadian Water Resources Journal, 6: 284–294.

Newbury, R.W., and G.K. McCullough. 1984. Shoreline erosion and restabilization in the Southern Indian Lake reservoir. Canadian Journal of Fisheries and Aquatic Sciences, 41: 558–565.

Newbury, R.W., G.K. McCullough, and R.E. Hecky. 1984. The Southern Indian Lake impoundment and Churchill River diversion. Canadian Journal of Fisheries and Aquatic Sciences, 41: 548–557.

Nikiforuk, A. 1986. The Frankenstein Project. Nature Canada, summer 1986: 42–43.

Petts, G.E. 1984. Impounded Rivers, Perspectives for Ecological Management. John Wiley and Sons. Toronto. 326 pp.

Rogers, P. 1983. The future of water. The Atlantic Monthly, July 1983: 80–92.

Sewell, W.R.D. 1983. Inter-basin water diversions: Canadian experiences and perspectives. United Nations Working Group on Environmental Impacts of Large Scale Water Development, Hamburg, West Germany. 49 pp.

Tritschler, G.E. 1979. Commission of Enquiry into Manitoba Hydro. Winnipeg, n.p.

Wagner, M.W. 1984. Postimpoundment change in financial performance of the Southern Indian Lake commercial fishery. Canadian Journal of Fisheries and Aquatic Sciences, 41: 715–719.

OXYGEN DEPLETION RATES IN SUBARCTIC LAKES NEAR SCHEFFERVILLE, QUEBEC

Oksana Choulik

Watershed Ecosystems Department, Trent University, Peterborough, Ontario K9J 7B8

Level: Master's

Abstract

Oxygen data from the late Frank Rigler's Limnology Project on subarctic lakes near the town of Schefferville, Quebec were analyzed. From 1977–1983, oxygen concentrations were monitored in seven lakes. Half of the lakes did not thermally stratify during summer because of their shallowness and alignment to the predominant NW winds, and remained saturated with oxygen. Of the stratified lakes, eutrophic Lake Elizabeth had the highest hypolimnetic oxygen depletion rate. It proceeded linearly with time at a rate of 0.391 g $O_2 \cdot m^{-2} \cdot day^{-1}$. Winter oxygen depletion proceeded linearly from the date of freeze-up in late October until early May, when the melting snow cover and increasing solar penetration through the ice cover resulted in an increase in photosynthesis and an increase in the concentration of whole-lake oxygen. Winter depletion rates ranged from 0.047 g $O_2 \cdot m^{-2} \cdot day^{-1}$ in oligotrophic Lake Dian to 0.225 g $O_2 \cdot m^{-2} \cdot day^{-1}$ in Lejeune. Rates appear to reflect the difference in trophic status rather than morphometric parameters.

Key words: Labrador-Quebec, subarctic, whole-lake oxygen depletion.

Résumé

Les mesures d'oxygène dans les lacs subarctiques proches de la ville de Schefferville, Québec du projet limnologique du regretté Frank Rigler ont été analysées. L'appauvrissement en oxygène entre 1977–1983 a été surveillé dans sept lacs. Les eaux de la moitié des lacs ne sont pas stratifiées thermiquement pendant l'été à cause de leur faible profondeur et de leur alignement aux vents prédominants du nord-ouest. Elles sont saturées en oxygène. Parmi les lacs stratifiés, le lac eutrophique Elizabeth a le taux de pertes d'oxygène hypolimnique le plus élevé. Ce taux décroit linéairement avec le temps à une vitesse de 0,391 g $O_2 \cdot m^{-2} \cdot jour^{-1}$. Les pertes d'oxygène hivernales diminuent linéairement à partir de quelques semaines après la glaciation, fin Octobre, jusqu'à début mai, quand la couverture neigeuse fondante et l'augmentation de la pénétration solaire à travers la couche de glace permet un accroissement de la photosynthèse et une augmentation de l'oxygène dans le lac entier. Les taux de diminution hivernale varient de 0,047 g $O_2 \cdot m^{-2} \cdot jour^{-1}$ dans la lac oligotrophique Dian à 0,204 g $O_2 \cdot m^{-2} \cdot jour^{-1}$ dans le lac Lejeune. Les taux semblent refléter les différences d'états trophiques plutôt que des paramètres morphométriques.

Mots-clés: Labrador-Québec, subarctique, appauvrissement hivernal d'oxygène.

Introduction

Fish biologists and limnologists have long been interested in the loss of oxygen from lakes during the winter. Oxygen depletion takes place when ice and snow prevent oxygen input to the lake through primary production and wind aeration, and the oxygen present in the lake is depleted by bacterial decomposition of organic matter. Depletion rates reported by most researchers have proceeded linearly over the winter time, though nonlinear rates have been observed (Babin and Prepas, 1985). Long lasting freeze-up of shallow lakes allows for midwinter anoxic conditions resulting in fish mortalities, more commonly called winterkill (Greenbank, 1945). Various methods, including snow clearing from lakes, have been tried to prevent winterkill conditions (Barica *et al.*, 1983).

Factors controlling oxygen depletion in ice-covered lakes can be divided into morphometric and trophic ones. Barica and Mathias (1979) found that rates of oxygen depletion in shallow, eutropic prairie lakes correlated with mean depth. Schindler (1971) found oxygen depletion in several northwestern Ontario lakes to be related to the volume and area of the lake and drainage basin, while it poorly correlated with mean depth. Welch *et al.* (1976) correlated it with mean depth, phosphorus concentration at spring overturn and summer chlorophyll a levels. Babin and Prepas, (1985) working on central Albertan lakes, discovered a correlation with lake productivity (total phosphorus and chlorophyll a levels) but not with mean depth. Welch and Bergmann (1985) found no correlation with lake depth for lakes near Saqvaqjuac, N.W.T.

Methods have been developed to try to predict anoxic conditions based on initial oxygen concentrations at the beginning of winter, the rate of oxygen depletion and mean/maximum lake depths (Barica & Mathias, 1979). The oxygen loss rate within individual lake strata can also be predicted from the oxygen concentration in each stratum 5–15 days after freeze-up (Jackson and Lasenby, 1982).

Figure 1. Location of Schefferville and lakes.

This paper presents the results of the oxygen data gathered by the late Frank Rigler's Limnology Project on the experimental addition of phosphorus and nitrogen to subarctic lakes near Schefferville, Quebec. Further details of the project itself can be found in Smith *et al.* (1985).

Study area

The seven lakes in this study are located within a 10 km radius of the town of Schefferville, Quebec (54° 49'N, 66° 50'W), a former iron ore mining town situated on the Labrador Trough of the Canadian Shield (Figure 1). Geologically, the area consists of ridges composed of quartzite, dolomite, iron and slates while the valleys are underlain by less resistant slates and dolomites. The Schefferville area lies in a transitional zone between boreal woodland to the south and tundra to the north. The vegetation is diverse and classified into the following communities: spruce-lichen woodland, spruce-feather moss forests, subalpine heath, alpine tundra and bogs (Waterway *et al.*, 1984).

The climate of the area has been classified as subarctic (Hare, 1950) and the mean annual temperature based on a 30 yr meterological record is −4.9°C., with monthly mean ranges of 12.5°C in July and −22.2°C in January. Mean annual snowfall based on a 30 year period is 378 mm water equivalent. Winds are predominantly from the NW and the average monthly windspeed is 16–20 km $\cdot hr^{-1}$. The lakes are ice covered for roughly seven and a half months of the year. Permanent freeze-up usually occurs by the end of October and ice-off occurs by mid-June.

Bryan (1965) estimates that 18–20% of the area is covered by lakes which are shallow, elongated and oriented NW. The lakes have two thermal periods (winter and summer), with two circulation periods in between (Choulik, 1985). During the summer, many lakes do not stratify because of their shallowness, elongated shape and NW-SE orientation of the long axis to the predominant NW-SE wind.

Table 1 gives morphometric and tropic data about the study lakes.

TABLE 1
Winter and summer oxygen depletion rates.

LAKE	ODR	r	n	mean ± SD
LEJEUNE				
winter 77–78	0.225	0.99	3	
winter 78–79	0.224	0.93	10	
winter 79–80	0.216	0.97	10	
winter 80–81	0.185	0.99	4	
winter 81–82	0.215	0.97	3	
winter 82–83	0.224	0.89	5	0.215 ± 0.015
HOPE				
winter 77–78	0.094	0.99	3	
winter 78–79	0.103	0.93	7	
winter 79–80	0.116	0.98	4	
winter 80–81	0.088	0.99	5	
winter 81–82	0.125	0.76	4	
winter 82–83	0.092	0.94	5	0.103 ± 0.015
MARYJO				
winter 77–78	0.062	0.99	4	
winter 78–79*	0.062	0.71	11	mean 77–80
winter 79–80	0.076	0.98	7	0.067 ± 0.008
winter 80–81	0.054	0.97	4	mean 80–83
winter 81–82	0.096	0.91	4	0.097 ± 0.043
winter 82–83	0.140	0.97	5	0.082 ± 0.032
ELIZABETH				
winter 77–78	0.136	0.97	3	
winter 78–79	0.204	0.99	10	
winter 79–80	0.136	0.99	5	0.159 ± 0.039
DIAN				
winter 77–78	0.052	0.99	3	
winter 78–79	0.047	0.75	9	
winter 79–80	0.081	0.98	5	0.060 ± 0.018
RIDGE				
winter 77–78	0.094	0.98	3	
winter 78–79	0.095	0.98	10	
winter 79–80	0.115	0.97	4	0.101 ± 0.012
DOLLY				
winter 77–78	0.066	0.97	4	
winter 78–79*	0.097	0.99	12	
winter 79–80	0.077	0.96	4	0.080 ± 0.016
LEJEUNE summer 78	0.230	0.99	5	
HOPE summer 78	NS		12	
MARYJO summer 78	NS		11	
ELIZABETH sum 78*	0.391	0.99	7	
sum 80	0.381	0.98	5	
DIAN summer 78	NS		12	
RIDGE summer 78	NS		12	
DOLLY summer 78*	NS		10	

Table 1. Winter and summer oxygen depletion rates (ODR) in g 0_2 m^{-2}. day^{-1} (r = correlation coefficient of each regression; n = number of sampling points; * = data taken from Chenard (1980).

Methods

Three lakes were sampled for oxygen from the summer of 1977 until the winter of 1982–1983. Whole-lake phosphorus concentration was doubled in Lejeune lake from 1979–1983 and from 1980–1983 in Maryjo and Hope Lakes. Dian, Dolly, Ridge and Elizabeth served as control lakes and were sampled from 1977–1980. Oxygen data for Dolly and Elizabeth lakes for 1978–1979 are from Chenard (1980). Each lake was visited 3–11 times, depending on available manpower, from just after freeze-up until a month and a half before ice-off occurred. At each visit water samples were collected over the deepest spot of the lake with either an aluminum drop-sleeve water bottle or a Masterflex peristaltic pump. Water samples were collected at two meter intervals from the top of the hydrostatic water level to just above the bottom sediments. The samples were fixed on the spot (Carpenter, 1965) and transported back to the laboratory for analysis.

Along with the oxygen samples, water samples for total phosphorus and chlorophyll a were also collected either at two meter intervals or with a Tygon tubing. Water temperature was determined by glass probe thermistor attached to a digital multimeter. Analyses procedures for oxygen, chlorophyll a and TP are given in detail in Chenard (1980).

The lakes were sounded with a Furuno depth sounder during the summers of 1977–1980. Bathymetric maps were drawn up and planimetered to give areas and volumes of individual stratum.

Oxygen mass was determined for each sampling day by multiplying the oxygen concentration of each stratum by its volume and then summing the figures to give whole-lake oxygen mass. The volume of the 0–2m stratum was corrected for ice thickness. Ice thickness data for all the lakes was not available, therefore data was used from Knob Lake, the official Atmospheric Environment Service ice survey lake for the region (Adams *et al.*, 1985). The whole-lake oxygen mass was then divided by the under-ice surface area of the lake to yield the areal oxygen mass (g $0_2 \cdot m^{-2}$) (Welch, 1974; Babin and Prepas, 1985). Winter oxygen depletion rates were then calculated by regressing the oxygen mass against days past freeze-up, with the slope of the regression giving winter oxygen depletion rates in g $0_2 \cdot m^{-2} \cdot day^{-1}$.

Summer oxygen depletion rates were calculated in a somewhat similar fashion, except instead of calculating whole-lake oxygen mass, only the change of oxygen in the hypolimnion was calculated. Areal oxygen mass was obtained by summing the mass of oxygen in the hypolimnion and then dividing by the surface area of the hypolimnion.

Winter rates were then regressed against spring and summer productivity (total phosphorus and chlorophyll a), mean depth, maximum depth and volume to give an idea of what factors influence winter oxygen depletion rates in lakes around Schefferville.

Results and discussion

Winter oxygen depletion rates

The study lakes during the 1977–1983 period froze over completely by November 16, October 17, October 29,

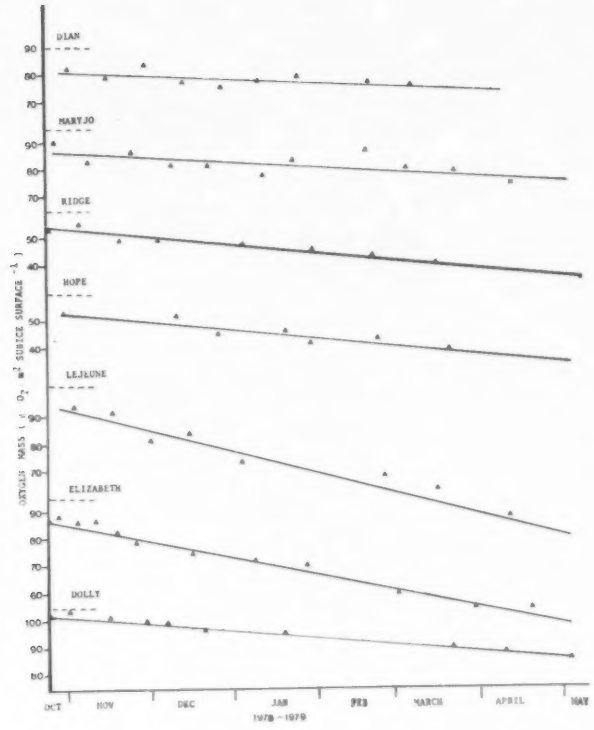


Figure 2. Winter oxygen depletion rates for 1978–1979.

October 20, October 30 and October 27, respectively. Ice cover lasted 214, 230, 223, 242, 231 and 225 days during those years. In some cases, an increase in lake oxygen mass was observed early in the winter, usually right after freeze-up, and was attributed to oxygen exsoluted from black-ice formation and from photosynthesis, if little snow cover was present. Oxygen depletion proceeded until early May. At this time the ice cover began to deteriorate and oxygen was added to the lake via inflows, melting snow and from increasing photosynthesis.

In all lakes the depletion of oxygen appeared to be a linear process. Seven lake-years with more than nine sampling points show a linear decrease in oxygen over the winter period. Figure 2 shows this linear decrease for the seven lakes over the winter of 1978–1979. For the other years there are less sampling points (3–7) but it is assumed from winter 1978–1979 data that the depletion rates are also linear. Previous studies have found depletion rates either to decrease linearly (Welch *et al.*, 1976; Mathias and Barica, 1980) as long as the average lake dissolved oxygen remained roughly above one to three mg $\cdot$ 1^{-1} or exponentially (Jackson and Lasenby, 1982; Babin and Prepas, 1985). Babin and Prepas (1985) suggest the following possible explanation for the nonlinearity of their data: the WODR for the Albertan lakes are based on a longer time interval than other studies on temperate lakes (120 days as compared with 90 days for Barica and Mathias (1980) and Welch *et al.* (1976) which in turn could have affected the rate of oxygen supply to the sediments. Another possible explanation is that some organic material in the sediments is more easily oxidized and used up first, causing a gradual decrease in oxygen depletion rates (Jackson and Lasenby, 1982). The Schefferville WODR is calculated for over a 200 day period and appear linear until the end of April, when the lake ice cover starts to visibly deteriorate.

Table 1 gives the rates of depletion and correlation coefficients for each lake over the six year period. Mean winter oxygen depletion rates varied from 0.060 g $O_2 \cdot day^{-1}$ in Dian Lake to .215 g $O_2 \cdot m^{-2} \cdot day^{-1}$ in Lejeune Lake. Means were worked out either for three years of data for all the lakes or for six years, as in the case of the fertilized lakes. Fertilized lakes had means worked out for pre-fertilization and then post-fertilization values.

Results of fertilization

Of the three fertilized lakes, only Maryjo responded to the treatment in the summer of 1982 (Smith *et al.*, 1984b). Mean summer chlorophyll a level increased from 0.66 mg $\cdot$ m^{-3} during the summer of 1981 to 3.20 mg $\cdot$ m^{-3} during the summer of 1982 (Table 1). This increase seems to be reflected in an increased oxygen depletion rate during the following winter. Pre-fertilization WODR for 1977–80 was 0.067–0.008 g $O_2 \cdot m^{-2} \cdot day^{-1}$. WODR during the winter of 1981–1982 was 0.096 g $O_2 \cdot m^{-2} \cdot day^{-1}$ and had increased to 0.140 g $O_2 \cdot m^{-2} \cdot day^{-1}$. It is not clear why only Maryjo Lake responded to P-addition. A possible explanation is that the phytoplankton in Maryjo consisted of a higher proportion of blue-green algae, that were able to fix N_2, than in other lakes. Unfortunately most of the summer's phytoplankton samples were destroyed on route to the laboratory in Montreal, and it is unknown what the phytoplankton composition in the lakes was.

Welch and Bergmann (1985) found no significant changes in phytoplankton production of Saqvaqjuac lakes after two years of only P-addition and no significance in pre- and post-fertilization respiration rates (WODR — freeze-out of oxygen from black ice formation). For two lakes that received both N and P, it was found that, in one lake after two summers of fertilization, the phytoplankton production had increased 77% while winter respiration had only increased 19%. Therefore, it appears that winter respiration could lag years behind increase in lake productivity and might not increase to the same degree.

No oxygen data exists for the Schefferville lakes that were fertilized with both P and N during the summer of 1983. Dian Lake was fertilized with P and N during the summer of 1981 and 1982 and showed an increase in chlorophyll a levels, but during the summer of 1983 Hope, Lejeune and Maryjo showed no such increases. The added nitrogen was either absorbed by benthic microbial communities or removed by bacterial denitrification (Smith *et al.*, 1984c).

TABLE 2
Mean WODR, depth and summer productivity values

LAKE	WODR	Z	Zmax	TPsp	TPsum	CHLasp	CHLasum	SD
MEAN 1977-1980								
LJ	0.222	18.5	8.1	4.0	4.8	1.1	1.4	6.9
H	0.104	11.0	4.2	5.1	4.2	1.1	0.87	8.2
MJ	0.067	19.5	8.2	2.4	2.1	0.75	0.68	9.2
E	0.159	27.1	9.9	17.4	23.7	3.6	5.3	3.6
Di	0.060	22.5	6.8	1.7	2.0	0.93	0.79	9.3
Do	0.080	23.8	8.8	1.1	1.3	0.38	0.45	10.6
R	0.101	11.3	3.9	4.5	4.1	0.84	0.95	6.9
MEAN 1980-83								
LJ	0.208	18.5	8.1	5.2	4.9	1.95	1.3	—
H	0.102	11.0	4.2	7.0	5.4	1.7	1.0	—
MJ	0.097	19.5	8.2	9.3	7.6	1.7	2.4	—

WODR = Winter oxygen depletion rate (g $O_2 \cdot m^{-2} \cdot day^{-1}$); Z = mean depth (m); Zmax = maximum depth (m); TPsp = spring total phosphorus ($mg \cdot m^{-3}$); TPsum = summer total phosphorus ($mg \cdot m^{-3}$); CHLa sp = spring chlorophyll a ($mg \cdot m^{-3}$); CHL a sum = summer chlorophyll a ($mg \cdot m^{-3}$); SD = secchi disk depth (m).

Summer oxygen depletion rates

Summer oxygen depletion was monitored in all the lakes during the summer of 1978, and in Elizabeth Lake during the summer of 1980. Only Lejeune, Maryjo and Elizabeth Lakes stratified and lost hypolimnetic oxygen. The stratification occurred from mid-July to mid-August, with the hypolimnion being gradually pushed deeper, until complete mixing occurred in late August. Oxygen depletion rates ranged from 0.153 g $O_2 \cdot m^{-2} \cdot day^{-1}$ in Maryjo to 0.391 g $O_2 \cdot m^{-2} \cdot day^{-1}$ in Elizabeth (Table 1). The other four lakes did not thermally stratify and remained saturated with oxygen.

WODR vs morphometric and trophic parameters

Table 2 gives winter oxygen depletion rates along with morphometric data (mean and maximum depth), mean total phosphorus concentrations (spring and summer), chlorophyll a concentrations (spring and summer) and secchi disk depth from the previous summer. When oxygen depletion rates were plotted against these parameters (Fig. 3, 4, 5 & 6),

TABLE 3
Correlation coefficients for WODR

Parameters	r value
Zmax	0.09
Z	0.26
TP spring	0.46
TP summer	0.46
Chla spring	0.48
Chla summer	0.45
SD	0.65

WODR = winter oxygen depletion rate (g $O_2 \cdot m^{-2} \cdot day^{-1}$); r = correlation coefficient of each regression; Zmax = maximum depth (m); Z = mean depth (m); TP = total phosphorus ($mg \cdot m^{-3}$); CHL a = chlorophyll a ($mg \cdot m^{-3}$); SD = secchi disk depth (m).

secchi disk depth gave the best correlation while maximum depth gave the worst (Table 3). The poor correlations could be a result of the lakes having similar mean depths, phosphorus and chlorophyll levels. Elizabeth Lake is greatly different in trophic state from the other six, which are similar to one another.

The correlations could have been improved if Lejeune Lake had been excluded from calculations. This lake appears to be an anomaly. It has the highest rate of oxygen depletion even though its phosphorus and chlorophyll concentrations are much lower than those found in Elizabeth Lake. Why this is so is unknown.

Comparisons with other studies show that lakes in arctic regions are only weakly correlated with mean depth or not correlated at all. Welch (1974) found no correlation between depth and lake respiration while Welch and Bergmann (1985) found a weak correlation with mean depth (r = 0.40). Studies from temperate lakes show the opposite. Welch *et al.* (1976) and Barica and Mathias (1979) found winter respiration rates of Ontario lakes and of small Manitoba prairie lakes to be strongly correlated with mean depth. Babin and Prepas (1985) for Albertan lakes though, found summer TP and Chl a levels correlated better with WODR than did mean depth. Welch and Bergmann (1985) feel that this lack of correlation with mean depth can be explained by lower summer temperatures and a lower proportion of planktonic respiration in arctic lakes than in temperate lakes.

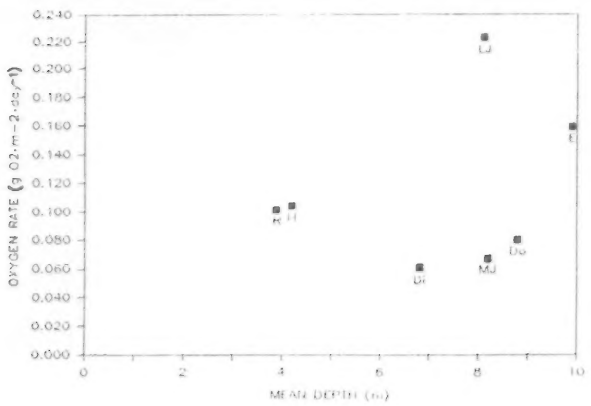


Figure 3. WODR versus mean depth.

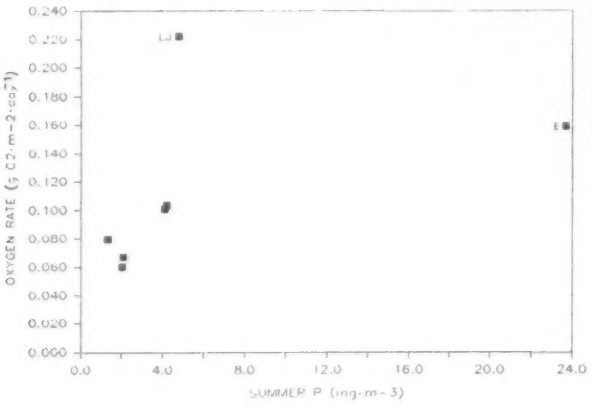


Figure 4. WODR versus TP summer

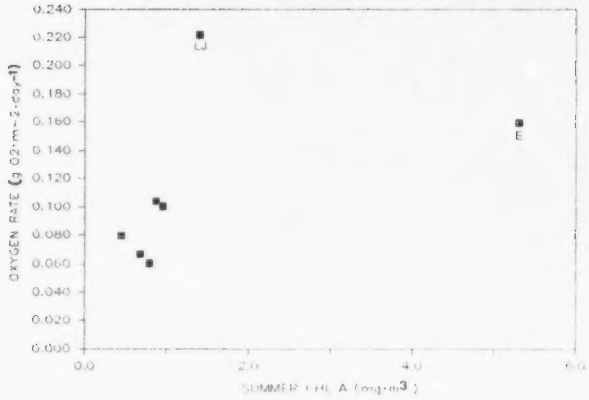


Figure 5. WODR versus Chla summer

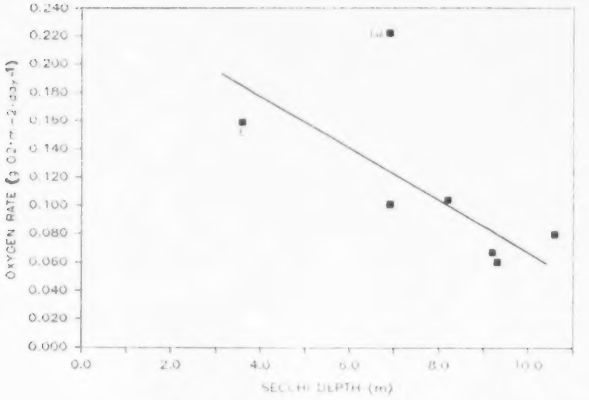


Figure 6. WODR versus secchi disk depth

Conclusion

The oxygen data from the Schefferville area show that lakes in the region decrease in oxygen in a linear fashion, with rates ranging from 0.046–0.225 g $O_2 \cdot m^{-2} \cdot day^{-1}$. In comparison with lakes in other regions, it appears that the Schefferville lakes deplete oxygen slower than do temperate lakes (Babin and Prepas, 1985) and lakes near Saqvaqjuac, N.W.T., (Welch and Bergmann, 1985) and around the same rate as lakes in northwestern Ontario (Schindler, 1974).

One would assume that the oxygen depletion rate of subarctic lakes would fall somewhere in between those of temperate and arctic lakes. This does not seem to be a fair assumption after one compares the Schefferville data with data from arctic lakes. Welch (1974) gives respiration values (WODR — oxygen freeze out from ice formation) of 0.087–0.254 g $O_2 \cdot m^{-2} \cdot day^{-1}$ for lakes near Resolute, Cornwallis Island. These values are not lower than the values for Schefferville lakes.

It could be that WODRs for the Schefferville lakes are underestimated. Possible sources of error are: a) too few sampling points over the winter, b) taking samples from only one spot of the lake and then assuming the rest of the lake also has the same oxygen concentration, c) using a mean of three drill holes on Knob Lake to represent ice thickness for all the study lakes. Babin and Prepas (1985) found that average dissolved oxygen values on Wizard Lake, Alberta were 47% higher when data from all six stations were used rather than data from the maximum depth site. Roulet and Adams (1984) found that the conventional single sample approach on a lake overestimates the quantity of light reaching the unfrozen water surface by 700%. This single point measurement is usually at the central or deep hole of the lake, and is usually the area with the least amount of snow and white ice and therefore the area with the greatest amount of light penetration. This spatial variability of light could lead to spatial variability in phytoplankton production and therefore to varying oxygen concentrations. Adams and Roulet (1980) demonstrated on Elizabeth Lake that the three components of winter lake cover (snow, white and black ice) vary spatially and that the one hole measurement technique could under- or overestimate total ice thickness considerably. And in an area like Schefferville, where the lakes are shallow, this can lead to a considerable error in oxygen depletion.

Acknowledgments

This project was made possible by generous grants from the Department of Indian and Northern Affairs Canada and from the Natural Sciences and Engineering Research Council to Frank H. Rigler. I would also like to thank A.C.U.N.S., the Northern Scientific Training Programme, and Peter Adams for supporting my work. I would like to thank Paul Chenard for his oxygen data from Dolly and Elizabeth Lakes. I am indebted to all the people who collected the data and were associated with the project: D. Barr, M. Bergmann, R. Dumas, H. & D. Evans, L. Huza, S. Griesbach, G. Kerheul, J. Lewis, T. Lei, T. & M. McNally, D. Musbach, V. O'Brien, M. Ostrofsky, S. Rabinovich, R. Shaw, D. Skraba, V.H. Smith, L. Turvey, A-M. Wau, L. Weber, F. Weicks, A. Westcott, B. Wolfe and C. Wood.

References

Adams, W.P., Barr, D.R. and Jackson, P. 1985. Archives of the ice record from Knob Lake, Quebec, 1954–present. Proceedings of the Eastern Snow Conference, 42.

Adams, W.P. and Roulet, N.T. 1980. Illustrations of the role of snow in the evolution of the winter cover of a lake. Arctic 31(1):100–116.

Babin, J. and Prepas, E.E. 1985. Modelling winter oxygen depletion rates in ice-covered temperate zone lakes in Canada. Canadian Journal of Fisheries and Aquatic Sciences 42:239–249.

Barica, J. and Mathias, J.A. 1979. Oxygen depletion and winterkill risk in small prairie lakes under extended ice cover. Journal Fisheries Research Board of Canada 36:980–986.

Barica, J., Gibson, J. and Howard, W. 1983. Feasibility of snow clearing to improve dissolved oxygen conditions in a winterkill lake. Canadian Journal of Fisheries and Aquatic Sciences 40:1526–1531.

Bryan, M.L. 1965. Lakes of the Knob Lake area, Labrador-Ungava: a study of morphology and morphometry. Unpublished M.Sc. thesis, Department of Geography, McGill University, Montreal, Quebec.

Carpenter, J.H. 1965. The Chesapeake Bay Institute technique for Winkler dissolved oxygen method. Limnology and Oceanography 10:141–143.

Chenard, P.G. 1980. Oxygen consumption in two subarctic lakes. Unpublished M.Sc. thesis, Department of Biology, McGill University, Montreal, Quebec.

Choulik, O. 1985. Lake temperatures in Quebec-Labrador lakes near Schefferville, Quebec. Unpublished Honours thesis, Department Watershed Ecosystems, Trent University, Peterborough, Ontario.

Greenbank, J. 1945. Limnological conditions in ice-covered lakes, especially as related to winterkill of fish. Ecology Monogram 15:344–392.

Hare, F.K. 1959. A photo-reconnaissance survey of Labrador-Ungava, Canada. Department of Mines and Technical Surveys Geological Branch 6, Ottawa.

Jackson, M.B. and Lasenby, D.C. 1982. A method for predicting winter oxygen profiles in ice-covered Ontario lakes. Canadian Journal of Fisheries and Aquatic Sciences 39:1267–1272.

Mathias, J.A. and Barica, J. 1980. Factors controlling oxygen depletion in ice-covered lakes. Canadian Journal of Fisheries and Aquatic Sciences 37:185–194.

Roulet, N.T. and Adams, W.P. 1984. Illustration of the spatial variability of light entering a lake using an empirical model. Hydrobiologia 109: 67–74.

Schindler, D.W. 1971. Light, temperature, and oxygen regimes of selected lakes in the Experimental Lakes area, northwestern Ontario. Journal Fisheries Research Board of Canada 28:157–169.

Smith, V.H., Rigler, F.H., Choulik, O., Diamond, M., Griesbach S. and Skraba, D. 1984a. Effects of phosphorus fertilization on phytoplankton biomass and phosphorus retention in subarctic Quebec-Labrador lakes. Verhandlungen die Internationale Vereinigung fur Theoretische und Angewandte Limnologie 22:673–687.

Smith, V.H., Rigler, F.H., Choulik, O., Diamond, M, Griesbach S. and Skraba, D. 1984b. A manual for eutrophication control in the subarctic. Indian and Northern Affairs Canada, Environmental Studies Number 33, Ottawa.

Smith, V.H., Rigler, F.H., Choulik, O., Diamond, D., Griesbach S. and Skraba, D. 1984c. Effects of nitrogen and phosphorus fertilization on lakes in Schefferville, Quebec. McGill Subarctic Research Paper 39:75–83.

Waterway, M.J., Lechowicz, M.J. and Moore, T.R. 1984. Vegetation of the Schefferville region, Nouveau Québec. McGill Subarctic Research Paper 39:7–20.

Welch, H.E. 1974. Metabolic rates of arctic lakes. Limnology and Oceanography 19:65–73.

Welch, H.E., Dillon, P.J. and Sreedharan, A. 1976. Factors affecting winter respiration in Ontario lakes. Journal Fisheries Research Board of Canada 33:1809–1815.

Welch, H.E. and Bergmann, M.A. 1985. Winter respiration of lakes at Saqvaqjuac, N.W.T. Canadian Journal of Fisheries and Aquatic Sciences 42(3):521–528.

NURSES AND INDIAN ELDERS/TRADITIONAL HEALERS: AN EXPLORATION OF THE CONTACT BETWEEN NON-TRADITIONAL AND TRADITIONAL HEALTH CARE PROVIDERS ON INDIAN RESERVES AND IN HEALTH CENTRES IN MANITOBA

David Gregory

School of Nursing, University of Manitoba, Winnipeg, Manitoba R3T 2N2

Level: Masters'

Abstract

An exploratory-descriptive, two phase, qualitative research design was implemented to examine the extent of collaboration/interaction between nurses and Indian Elders/traditional healers in Manitoba. Phase I consisted of semi-structured, face to face interviews with Medical Services Branch nurses (N = 10) and Indian Elders (N = 13) on three northern Indian reserves. Phase II administered a close-ended, structured, census survey mail questionnaire to nurses (N = 64) working autonomously with Indian clients.

Interviews with nursing staff (Phase I) provided eight case studies where interactive and to a lesser extent, collaborative client treatment efforts between nurses and members of the traditional health care system had occurred. Indian people were identified as utilizing both health care systems (traditional and Western) in the procurement of symptom relief. The belief that traditional healers wish to maintain a clandestine presence in relation to the dominant health system was challenged by the Elder informants.

Based on an 81.2% survey return rate, 52% (N = 27) of the nurses had initiated client referrals to Elders, while 39% (N = 20) had made client referrals to traditional healers. Patients asked 40% (N = 21) of the nurses for referral to a traditional healer. The majority of the nurses (67%) were aware of traditional healing practices in their communities.

Key words: Nurses, Indian reserves, Elders, traditional healers, Manitoba.

Résumé

L'auteur a suivi un plan de recherche qualitative en deux phases (exploratoire et descriptive), afin d'analyser l'ampleur de la collaboration et des interactions entre les infirmières et les Anciens et guérisseurs parmi les Amérindiens du Manitoba. La première consista en entrevues personnelles semi-structurées avec les infirmières de la Direction des services médicaux (nombre = 64) et les Anciens des Amérindiens (n = 13) dans trois réserves indiennes du Nord. La seconde phase comprit un relevé structuré et circonscrit grâce à l'envoi postal d'un questionnaire aux infirmières (n = 64) qui oeuvrent de façon autonome pour leur clientèle amérindienne.

Les entrevues menées avec le personnel infirmier (1ère phase) ont permis de compiler huit études de cas d'interactions et, sur une moindre envergure, de collaboration entre infirmières et membres du réseau traditionnel de prestation des soins. On note que les Indiens s'adressent aux deux réseaux de santé (traditionnel et occidental) pour être soulagés de leurs symptômes maladifs. Les Anciens interrogés ont nié que les guérisseurs cherchent à maintenir une présence clandestine, parallèlement au réseau de santé dominant.

Selon les résponses au questionnaire renvoyé par 81,2% des personnes interrogées, cinquante-deux pour cent des infirmières (n = 27) avaient envoyé des malades à un Ancien, et 39% (n = 20) à un guérisseur. Les malades avaient demandé à 40% des infirmières (n = 24) de les envoyer à un guérisseur. La majorité des infirmières (67%) connaissent

les méthodes traditionnelles de traitement utilisées dans la collectivité où elles oeuvrent.

Mots-clés: Infirmières, réserves indiennes, Anciens, guérisseurs, Manitoba.

Introduction

A cultural and linguistic revival has been identified as taking place on Indian reserves in Canada (Adams, 1984). One area of Indian cultural renaissance is health care, specifically the utilization of traditional practices (Government of Canada, 1983). The resurgence and revitalization of traditional Indian health care practices presents health care practitioners with a significant challenge in providing quality client-centered health care.

Jilek (1982) contended that it is not due to the lack of modern treatment services that a revival of indigenous healing ceremonials has occurred. "It has to do with a lack of culture-congenial and holistic approaches to modern medicine" (Jilek, 1982, p. 161). In general terms, the dominant health system is currently perceived as a less effective system and it is the general consensus that the health demands of Canada's Indian population are not being met by western medicine (Kennedy, 1984).

Elders and traditional healers are being approached by an increasing flow of natives seeking advice and counsel, healing and inspiration, interpretation of the past and present, which are the prerequisites for future survival (Couture, 1979). Few programs however, are in existence which formally integrate the available health care resources. The western or dominant health care system and the existing traditional Indian health beliefs and practices have not been melded into a culturally congenial system for Canada's Indian people (Kennedy, 1984).

Nurses as primary health care workers can impede or enhance recent Indian cultural developments through manipulation of institutional powers and nursing practices. Referring clients to traditional healers and/or Elders would enhance the holistic approach which the nursing profession advocates and would assist Indian clients in preserving and developing their own health values.

Previous nursing research has not examined the extent of collaboration/interacton between nurses and Indian Elders and the degree of contact with traditional healers in Manitoba. Therefore, an exploratory-descriptive, two phase qualitative research design was implemented to address this knowledge deficit. In Phase I, an open end, semi-structured, face-to-face interview was administered to nurses (n = 10) and Elders (n = 13) on three Indian reserves in northern Manitoba. These communities were identified by an Indian informant as being active in traditional Indian medicine. Phase II consisted of a structured, census survey mail questionnaire administered to Medical Services Branch (MSB) nurses (N = 64) throughout the province of Manitoba. This exploratory-descriptive study was implemented to examine the extent of interaction and collaboration between MSB nurses and members of the traditional health care system.

Field interviews with nurses and Elders/traditional healers

Interviews with the nursing staff (Phase I) provided eight case studies where interactive and collaborative client treatment efforts between nurses and members of the traditional health care system had occurred. The case studies clearly demonstrated that Indian people were utilizing both health care systems to procure relief with their health problems. The clients in the case studies appeared comfortable in using either health care system in the quest for successful treatment.

The fact that Indian people are making use of both Western and traditional healing systems has significant implications for health care providers active in the care and treatment of Indian clients. To deny the potency or efficaciousness of the traditional health care system undermines any attempts by the native people to develop and preserve their own health care modes. The utilization of both health care systems by the Indian people also supports the need for recognition of the non-formal health care system and indeed, supports the need for integrative approaches to the provision of native health care.

Of the 13 Elders interviewed, one was a medicine woman, four Elders were medicine men, and one Elder was identified as a dream interpreter after the interview. The remaining seven research subjects did not identify themselves as healers. Field interviews with the Indian Elders yielded rich and valuable data.

It was suggested by the Elders that nurses need to know healers' identities. Moreover, Elders supported informing the nurses as to the identities of healers in the Indian communities. Cross referrals were identified by the Elders as one reason for informing the nurses about the community healers. The Elders advocated cross referral and suggested that clients/patients who did not receive relief from their symptoms in the dominant health care system would benefit from consultation with traditional healers.

The following example demonstrates a positive health outcome resulting from a combination of the two health care systems. The dominant health care system was unable to provide relief for the patient and therefore consultation with a traditional healer was initiated by the patient's family. The medicine man supported the findings of the nurses and physician and assisted the patient and her family in accepting the dominant health care system's diagnosis and treatment. The traditional healer in this example was an asset to the dominant health care system.

Case I

> We had a young girl 12 years old who was coming into the nursing station continuously with chest pain and many other things. We examined her completely and couldn't find a thing. We sent her to Dr. (Thompson physician) who examined her from head to toe, including total body X-rays because she had aches everywhere. He couldn't find anything at all. We decided in collaboration that she was probably trying to avoid school. As a prenote, the problem started when she started to menstruate for the first time on the trapline. For a lot of girls it's a big shock, but starting out on the trapline was probably quite a shock to her. Her family decided that if we weren't going to do anything for her, they were going to take her to a medicine man in (location). The medicine man told her that the

> problem was all in her head, and that she should pull herself together and start helping other people and forgetting herself. That was a direct quote from her uncle who had been told by her father and mother. We hadn't referred her because it had never occurred to me to do so in this particular case. It did work out however . . . everything the medicine man said supported what we already said. The girl got better.

It was evident from the interviews with the nurses that several of them were in direct contact with various members of the traditional health care team. It should be noted that this contact resulted from a personal (a perhaps professional) interest and appreciation of the traditional healing system and not as a result of official Medical Services policy.

Nurses who demonstrated a sincere interest and appreciation for the traditional healing system were entrusted with much information concerning the healers and their practices. That traditional healers currently wish to remain underground or maintain a clandestine presence in relation to the Western health care system was challenged in both phases of this study. The Elders/traditional healers and nurses offered congruent and consistent information supporting the willingness of the healers to collaborate with members of the dominant health care system.

Interaction between Medical Services nurses and Elders/traditional healers: a census survey

The entire population of Medical Services Branch nurses and band employed nurses who possessed autonomy (that is, the ability to initiate independent or interdependent treatment regimens in the active care of Indian clients) within the province of Manitoba (N = 64) was surveyed. A return rate of 81.2% (n = 52) from the nurses surveyed provided credibility to the findings in Phase II of the study.

Traditional and non-traditional health system interaction

Nurses appeared to be active in the referral of clients to Elders for counselling purposes. Of the nurses surveyed, 52% (n = 27) reported that they had initiated client referrals to Indian Elders. Of the clients referred, 59% (n = 16) were identified by the nurses as experiencing positive outcomes. That is, the client received relief from his/her problem as a result of the referral. Negative results in which the client did not receive relief from his/her problem were reported for 11% (n = 8) of the referrals. Nurses were unaware of the results in approximately 30% (n = 8) of the client referrals initiated.

The majority of the nurses (67% n = 35) were aware of traditional healing practices in their communities. The percentage of nurses who actively referred clients to traditional healers was substantially lower than the Elder referrals. For example, 38% (n = 20) of the nurses reported they had initiated client referrals to traditional healers. Clients asked 40% (n = 21) of the nurses for a referral to a traditional healer in other Indian communities.

TABLE 1
Synopsis of Nurse-Elder/Healer Interaction*

	Yes	No
1. Nurse initiated client referral to Elders.	52% (27)	48% (25)
2. Nurse initiated client referral to trad healer.	39% (20)	61% (32)
3. Aware of trad healing in the community?	67% (35)	25% (13)
4. Patient requests for trad healer?	40% (21)	
5. Inclusion of Elders in health programs?	42% (22)	58% (30)
6. Inclusion of healers in health programs?	19% (10)	81% (42)

* percentages have been rounded off

The inclusion of Elders in community health programs was identified by 42% (n = 33) of the nurses, while traditional healers were included in 19% (n = 10) of these programs. Table 1 provides a synopsis of the interaction between nurses and Elders/traditional healers. Four client referral patterns (see Table 2) were identified among the nurses.

Summary and conclusion

More than 1/2 (52%) of the nurses appeared to be active in the referral of clients to Elders for counselling purposes and the majority of the MSB nurses (67%) were aware of traditional healing practices within their communities throughout the province of Manitoba. Overall, the nurses' perceptions of Indian Elders and traditional healers was positive. Both the Elders and healers were viewed as complementing the dominant health care system and the vast majority of the nurses (92% n = 48) stated that they would be willing to

TABLE 2
Referral Patterns to Elders/Healers by Nurses*

	Elder Referral	Healer Referral	% Nurses
Pattern I	Yes	Yes	37 (16)
Pattern II	No	No	40 (21)
Pattern III	Yes	No	21 (11)
Pattern IV	No	Yes	7 (4)

* percentages have been rounded off
N=52

collaborate with Elders, especially if this practice was supported by their supervisors. Nurses on their own initiative, were relatively active in the referral of clients to Elders and traditional healers.

The findings of this study have significant implications for nurses (and other health care practitioners) in both rural and urban settings who provide care for Indian clients. Acknowledgement and support of the Indian client's own traditional health care system where appropriate, could significantly contribute to an improvement in his/her health status. Indian people are utilizing both health care systems in their quest for symptom relief. Nurses, other health care practitioners and Medical Services need to be supportive of this practice.

References

Adams, J. (1984, October 9). Linguistic, cultural revival underway on reserves. The Citizen, Ottawa, p. C10.

Couture, J. (1979). Next time, try an elder! (Draft), Department of Native Studies, Trent University, Peterborough, Ontario. To be published in Flower of two soils: American Indian youth in transition. Edited by M. Berser, University of Washington Press, Seattle, 1979.

Government of Canada. (1983). Minutes of proceedings of the special committee on Indian self-government. Mr. Keith Penner, Chairman. Ottawa.

Jilek, W. (1982). Indian healing: Shamanistic ceremonialism in the Pacific northwest today. Surrey: Hancock House.

Kennedy, D. (1984). The quest for a cure: A case study in the use of health care alternatives. Culture IV, Vol (2), p. 21-31.

DEMOGRAPHIC CHANGES IN CYCLIC POPULATIONS OF ARCTIC FOX (*ALOPEX LAGOPUS*) AT ESKIMO POINT, N.W.T., CANADA

Michael N. Hall and F.F. Mallory

Department of Biology, Laurentian University, Sudbury, Ontario P3E 2C6

Level: M. Hall, Master's

Abstract

Arctic fox populations, in the central Canadian Arctic, cycle every 3- to 4- years in an apparent response to changes in microtine density (Macphearson, 1969). In an attempt to analyse the population dynamics of this species in greater detail, 693 Arctic fox carcasses have been obtained from Inuit trappers at Eskimo Point, N.W.T., during regular trapping seasons (Nov. 1 to Apr. 15) since the fall of 1983.

Basic morphometric parameters on whole body and organ components were measured and tissue samples of brain and diaphragm collected. In addition, the reproductive and digestive tracts, canine teeth and the right femur were taken for further analysis. Female reproductive tracts were examined for placental scars and for variations in uterine and ovarian weight.

Digestive tracts were examined for evidence of food habits and endoparasitic load.

Brain tissue samples have been tested for rabies using the flourescent antibody technique. An index (0 to 4) of subcutaneous fat reserves was correlated with bone marrow fat levels as a means of establishing a quick and simple technique for future assessment of relative physical condition. Age estimates for individual animals were obtained by examining the cementum annuli of canine teeth.

Preliminary morphometric analysis indicates that fox populations change qualitatively on a seasonal and multiannular basis and that demographic changes are correlated with population density and prey abundance.

Key words: *Alopex*, Arctic fox, demography.

Résumé

Les populations de renards arctiques de l'Arctique central du Canada subissent des variations cycliques durant 3 ou 4 ans en réponse apparente aux modifications de densité des populations d'arvicolinés (Macphearson, 1969). En vue d'analyser la dynamique de la population de renards arctiques, les auteurs ont recueilli 693 de leurs carcasses auprès des trappeurs inuit d'Eskimo Point, T.N.-O., au cours des saisons habituelles de piégeage (du 1er nov. au 15 avr.), depuis l'automne de 1983.

Ils ont mesuré les caractéristiques morphologiques fondamentales du corps et des organes de ces animaux, et prélevé des échantillons de leur cerveau et de leur diaphragme. En outre, les organes reproducteurs et digestifs, les canines et le fémur droit furent conservés pour étude subséquente. Ils ont examiné les organes femelles de reproduction pour dénombrer les cicatrices placentaires et les variations du poids de l'utérus et des ovaires.

Ils ont étudié les organes digestifs pour déterminer le régime alimentaire et évaluer l'infestation d'origine parasitaire. Ils ont soumis les échantillons de cerveau au test de la rage, par la technique de l'anticorps fluorescent. Ils ont établi les corrélations entre un indice (de 0 à 4) des réserves graisseuses sous-cutanées avec la teneur de la moelle osseuse en gras, en vue d'élaborer une technique simple pour l'évaluation future de la condition physique relative de ces animaux. Ils ont évalué l'âge de certains d'entre eux en examinant le cément de leurs canines.

Les résultats préliminaires de l'analyse morphologique indiquent que les populations de renards arctiques fluctuent

qualitativement selon des cycles saisonniers et pluriannuels et que les changements numériques sont fonction de la densité de population et de l'abondance des proies.

Mots-clés: *Alopex*, renard arctique, population.

Introduction

Throughout most of their distribution arctic fox (*Alopex lagopus*) populations fluctuate every 3 to 4 years, closely following the population dynamics of microtines, their principle winter prey (Elton, 1942; Remmert, 1980).

The importance of the arctic fox to native peoples as a furbearer (Macphearson, 1969; Tinling, 1982) and its role as a vector for rabies (Ramsden and Johnston, 1975; Mallory and Dieterich, 1985), justifies the examination of detailed changes in populations during population cycles.

The main objectives of this study were to monitor physiological, morphometric, and pathological parameters associated with arctic fox populations during all phases of a complete population cycle. This paper presents preliminary morphometric data on female foxes trapped near Eskimo Point, N.W.T. between 1983–1986, and discusses the results in relation to current theories on the dynamics of predator-prey systems.

Materials and methods

Six hundred and ninety three arctic fox carcasses were purchased from Inuit trappers at Eskimo Point, N.W.T., Canada. Animals obtained were from an area ranging from northern Manitoba (Nunalla) to the upper end of Kaminuriak Lake, N.W.T. Purchases were made from 1983 to the present during the regular trapping seasons (November 1–April 15).

Colour phase, trapper's name, date and location captured were recorded for each specimen. Standard morphometric parameters measured were total length, tail length, condylobasal breadth, zygomatic length, body weight and weights of heart, lung, liver and spleen. Reproductive and digestive tracts, right femurs, canine teeth and brain cores were taken for further analysis. Subcutaneous fat was visually estimated using a 0 to 4 index (0- no fat reserves; 4- abundant fat reserves). The data were analysed for seasonal and multiannular trends and compared to data on microtine abundance, obtained from trap-line census near Eskimo Point, N.W.T.

Results

Monthly mean weights of animals for the three year study period decreased from November to April (Figs. 1a, b, c) though the weights of 1983–84 animals (Fig. 1a) fluctuated less overall than did those of animals in 1984–85 (Fig. 1b) and in 1985–86 (Fig. 1c).

Seasonal subcutaneous fat levels (Figs. 2a, b, c) increased initially from November to December in each year followed by an overall decrease in values for the remainder of the trapping period (January to April). In the 1983–84 and 1984–85 trapping seasons, but not in 1985–86 (Fig. 2c), subcutaneous fat was significantly lower during January (Figs. 2a, b), and recovered slightly in February.

The ratio of liver size to body weight decreased from a high in the early part of the season to a low in March (Figs. 3a, b, c). Relative liver weight was higher during the 1983–84 trapping seasons than in the subsequent two years (1984–85, and 1985–86). In each year, with the exception of 1985–86, November ratios were highest compared to all other months (Figs. 3a, b, c). The animals in 1983–84 maintained consistently higher values than animals in other years.

Kidney/body weight ratios indicated that kidney size relative to body weight was constant during the entire trapping season; however, major differences were observed between years (Figs. 4a, b, c). Relative kidney weights were significantly lower during 1983–84, than 1984–85 and 1985–86. No apparent difference was noted for the last two years.

Changes in the relative density of the collared lemming (*Dicrostonyx groenlandicus*) population at Eskimo Point, N.W.T. are indicated in Figure 5. The lemming population was lowest in 1983, intermediate in 1984, very high in 1985, and then crashed in 1986.

Discussion

Total body weights were higher in November and decreased steadily until March. These results are similar to those found by Underwood (1971) working on arctic fox at Barrow, Alaska. These seasonal changes were similar for all years studied and the loss of weight was gradual in all cases. No apparent difference occurred between years, as has been demonstrated in other circumpolar species (Kalela, 1957; Chitty and Chitty, 1962; Mallory et al., 1986). These results support the conclusion that major seasonal, but not multiannular changes in body weight occur in this species.

The subcutaneous fat index also indicated that seasonal changes occurred. Fat deposition continued to rise between November and December and gradually declined to minimal levels in April. Underwood (1971) found similar results working in Alaska. However, Hammil (1983) found that arctic fox trapped on Victoria Island, N.W.T., had higher fat deposits in March and April than those caught in November. This apparent difference may be due to the fact that many of the Victoria Island animals moved onto the ice and fed on seal pups.

In both 1983–84 and 1984–85 when lemming numbers were low to moderate (Fig. 5), the January subcutaneous fat levels dropped significantly, recovering again in February. This did not occur in 1985–86 when lemming numbers were high. These data suggest that differences in prey density were responsible for maintaining higher levels of condition in overwintering foxes. The recovery of subcutaneous fat levels in February is not understood at this point, but may represent a switch to alternate prey.

Liver/body weight ratios declined steadily from November to March in all years (Figs. 3a, b, c). However, the animals in 1983–84, the year of low lemming density, had consistantly higher values than those from the other two years. The reasons for this difference are not presently known; however, food shortage and low glycogen levels may have stimulated hypertrophy in this organ.

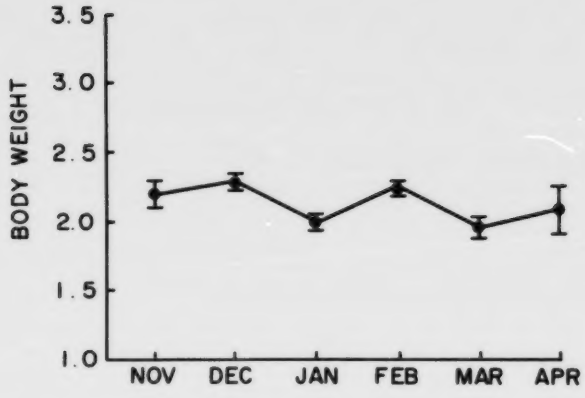


Figure 1a. Mean weights (Kg) of female arctic fox trapped near Eskimo Point, N.W.T. during 1983–84 (November to April)

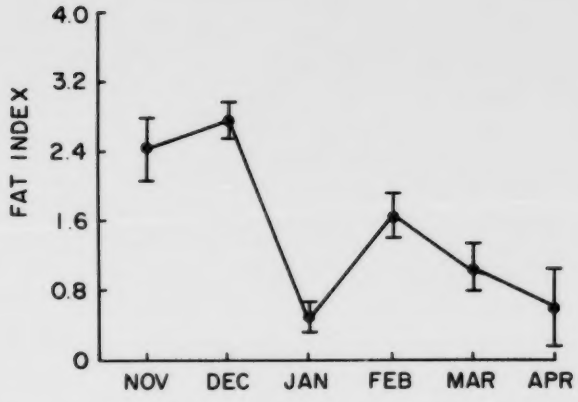


Figure 2a. Mean fat index values of female arctic fox trapped near Eskimo Point, N.W.T. during 1983–84 (November to April)

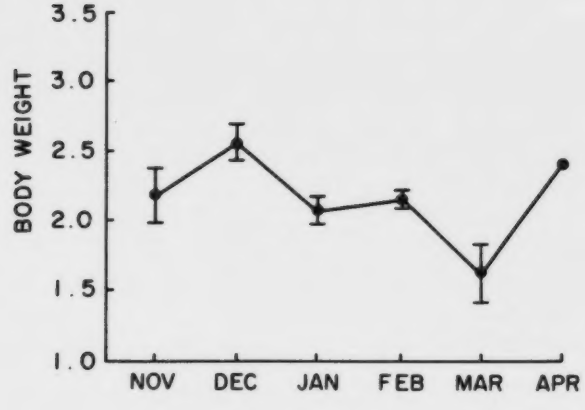


Figure 1b. Mean weights (Kg) of female arctic fox trapped near Eskimo Point, N.W.T. during 1984–85 (November to April)

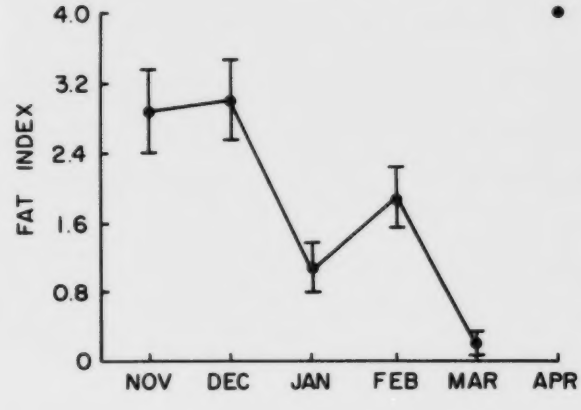


Figure 2b. Mean fat index values of female arctic fox trapped near Eskimo Point, N.W.T. during 1984–85 (November to April)

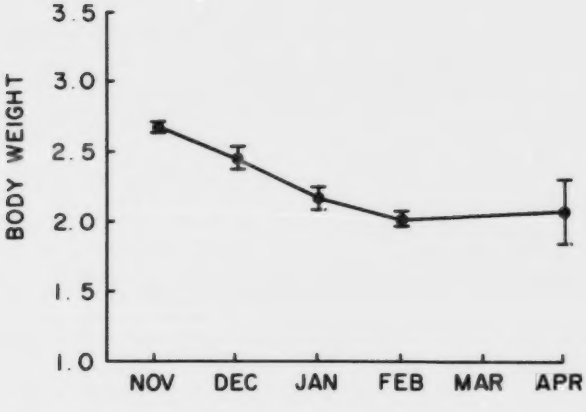


Figure 1c. Mean weights (Kg) of female arctic fox trapped near Eskimo Point, N.W.T. during 1985–86 (November to April)

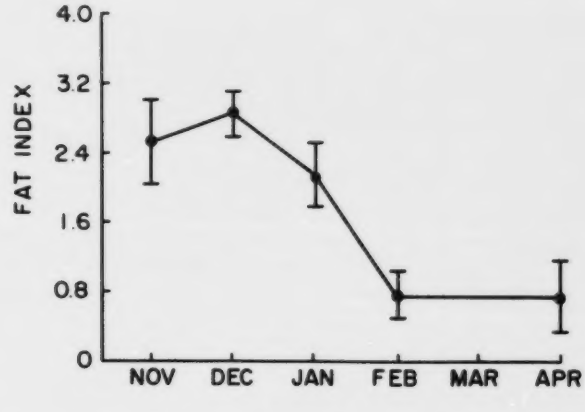


Figure 2c. Mean fat index values of female arctic fox trapped near Eskimo Point, N.W.T. during 1985–86 (November to April)

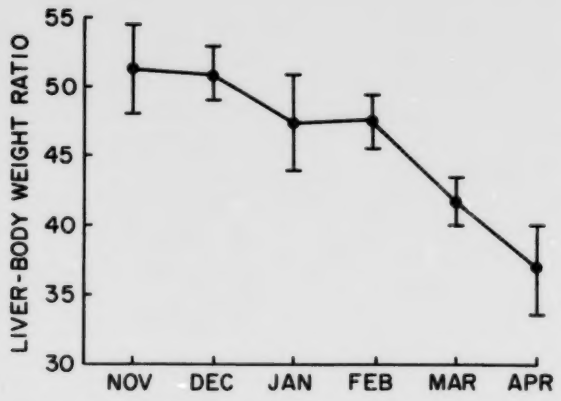


Figure 3a. Liver/body weight ratios (×10) of female arctic fox trapped near Eskimo Point, N.W.T. during 1983–84 (November to April)

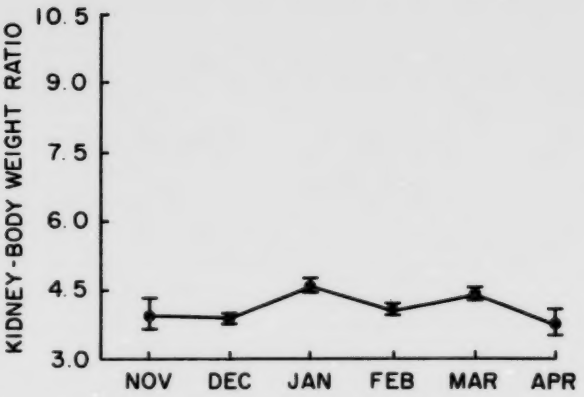


Figure 4a. Kidney/body weight ratios (×10) of female arctic fox trapped near Eskimo Point, N.W.T. during 1983–84 (November to April)

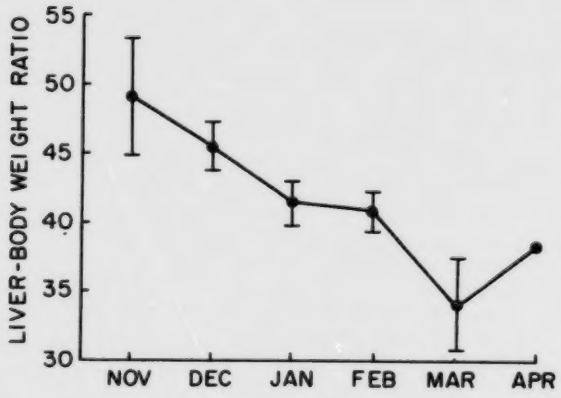


Figure 3b. Liver/body weight ratios (×10) of female arctic fox trapped near Eskimo Point, N.W.T. during 1984–85 (November to April)

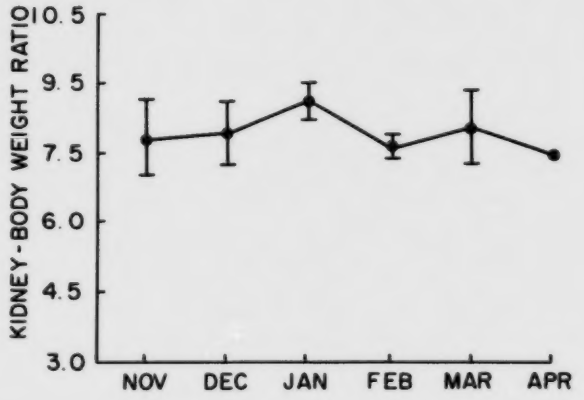


Figure 4b. Kidney/body weight ratios (×10) of female arctic fox trapped near Eskimo Point, N.W.T. during 1984–85 (November to April)

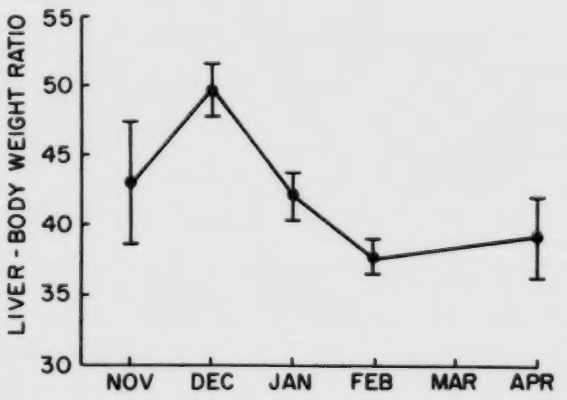


Figure 3c. Liver/body weight ratios (×10) of female arctic fox trapped near Eskimo Point, N.W.T. during 1985–86 (November to April)

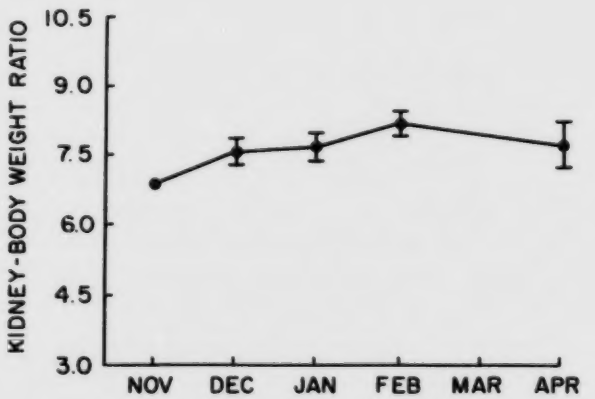


Figure 4c. Kidney/body weight ratios (×10) of female arctic fox trapped near Eskimo Point, N.W.T. during 1985–86 (November to April)

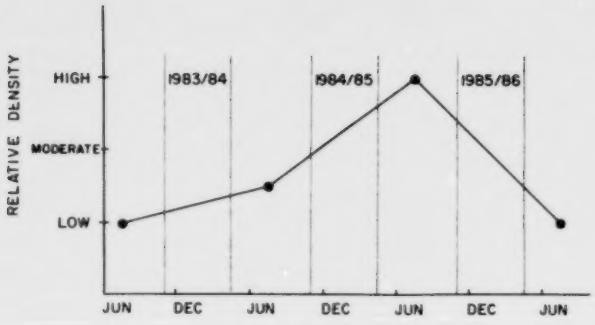


Figure 5. Relative *Dicrostonyx groenlandicus* near Eskimo Point, N.W.T. Vertical lines with inset years represent arctic fox trapping seasons.

The data on kidney/body weight ratios indicates that little change occurs during the winter season. However, significant differences were noted between years (Figs. 4a, b, c) with the lowest values occurring in 1983–84, when lemming numbers were lowest. As the major function of the kidney is to excrete nitrogenous wastes, low protein intake may cause renal hypotrophy and a reduced excretory rate.

The data presented in this paper are preliminary, but support the conclusion that major morphometric and physiological changes occur in arctic fox populations between seasons and during the population cycle.

Acknowledgments

The authors wish to thank Ben Kovic, Patricia Dwyer, Chris Bloome and Noah Muckpah for technical assistance. Rabies analysis was provided by the Animal Pathology Laboratories of Agriculture Canada at Lethbridge and Sackville. Logistic support was provided by the N.W.T. Wildlife Service and the project was funded by the Science Institute of the N.W.T., the Natural Sciences and Engineering Research Council of Canada, and Laurentian University.

References

Chitty, H., and Chitty, D. 1962. Body weight in relation to population phase in *Microtus agrestis*. Symposium Theriologicum (Brno, 1960): 77–86.

Elton, C. 1942. Voles, mice and lemmings: problems in population dynamics. Clarendon Press, Oxford. 496 p.

Hammil, M.O. 1983. The arctic fox, *Alopex lagopus*, as a marine mammal; Physical condition and population age structure. Unpublished M.Sc. Thesis. Institute of Oceanography, McGill University, Montreal. 72 p.

Kalela, O. 1957. Regulation of reproduction rate in subarctic populations of the vole *Clethrionomys rufocanus* (Sund.). Annale Academica Scientifica Lennae A, IV:1–60.

Macphearson, A.H. 1969. The dynamics of Canadian arctic fox populations. Canadian Wildlife Report Series No. 8, Ottawa. 52 p.

Mallory, F.F., and Dieterich, R.A. 1985. Pathology and laboratory management. In Biology of New World *Microtus*. A special publication of the American Society of Mammalogists. Tamarin, R.H. ed. 893 p.

Mallory, F.F., Brooks, R.J., and Elliott, J.R. 1986. Variations of skull-body regressions of the lemming (*Dicrostonyx groenlandicus*) under laboratory and field conditions. Zoological Journal of the Linnean Society. 87:125–138.

Ramsden, R.O. and Johnston, D.H. 1975. Studies on the oral infectivity of the rabies virus in Carnivora. Journal of Wildlife Disease, 11:318–324.

Remmert, H. 1980. Arctic animal ecology. Springer-Verlag, Berlin. 250 p.

Tinling, R. 1982. Northwest Territories fur production, 1957–58 to 1978–79. N.W.T. Wildlife Service. Information Report No. 1.

Underwood, L.S. 1971. The bioenergetics of the arctic fox (*Alopex lagopus* L.). Unpublished M.Sc. Thesis. The Pennsylvania State University. 85 p.

DISTRIBUTION AND ABUNDANCE OF THE WHITE WHALE (*DELPHINAPTERUS LEUCAS*) IN RELATION TO THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE CHURCHILL RIVER ESTUARY

S.E. Hansen, P.D. Watts, and F.F. Mallory

Department of Biology, Laurentian University, Sudbury, Ontario P3E 2C6

and

Institute of Arctic Ecophysiology, Churchill, Manitoba R0B 0E0

Level: S. Hansen, Master's

Abstract

During the summers of 1982–1986, systematic oceanographic surveys were conducted with simultaneous aerial surveys to study the distribution and abundance of White Whales (*Delphinapterus leucas*) in relation to water temperature, salinity, and turbidity in the Churchill River estuary. There was a positive correlation between the distribution of White Whales in the study area and water temperature. The whales congregated in areas where maximal water temperatures were recorded. The warmest water temperatures (23°C maximum) occurred in the area where the Churchill River flowed into the estuary. The daily abundance of whales during the season was positively correlated with the water temperature gradient between the warmest water in the estuary and the coastal waters. The whales entered the estuary in late June when spring breakup occurred. The number of whales increased rapidly and peaked when the temperature gradient was maximal. Numbers declined to zero during the early part of September, corresponding to the minimal temperature gradient for the season. This supports the hypothesis that White Whales utilize specific arctic estuaries in summer

for the thermal advantage that such estuaries present to all age classes.

Keywords: White Whales, Beluga Whales, aerial surveys, oceanography, water temperature, salinity, turbidity, Churchill estuary.

Résumé

Les auteurs ont mené des relevés océanographiques systématiques au cours des étés de 1982 et 1983, parallèlement à des relevés aériens, afin d'étudier la répartition et l'abondance des bélougas (*Delphinapterus leucas*) en fonction de la température, de la salinité et de la turbidité des eaux de l'estuaire du fleuve Churchill. Ils ont établi une corrélation positive entre la répartition des bélougas et la température de l'eau dans la région observée. Ces baleines se rassemblent dans les eaux les plus chaudes. C'est au point où le fleuve pénètre dans son estuaire que la température maximale des eaux (23°C) a été observée. Les auteurs ont établi une corrélation positive entre l'abondance estivale quotidienne des bélougas en saison avec le gradient de température entre les eaux les plus chaudes de l'estuaire et les eaux du littoral. Les bélougas pénètrent dans l'estuaire du fleuve Churchill en fin juin, au moment de la débâcle, accroissant rapidement leur nombre jusqu'au moment du gradient maximal de température. Leur nombre diminue ensuite jusqu'à zéro au début de septembre, moment du gradient minimal de température de l'été. Ces observations étayent l'hypothèse selon laquelle les bélougas de toutes les classes d'âge visitent en été certains estuaires de l'Arctique pour profiter de la température clémente des eaux.

Mots-clés: Baleine blanche, bélouga, relevés aériens, océanographique, température des eaux, salinité, turbidité, estuaire du Churchill.

Introduction

Large aggregates of white whales (*Delphinapterus leucas*) annually move into the estuaries of arctic rivers during the summer (Sergeant and Brodie, 1969, 1975; Brodie, 1971; Sergeant, 1973; Finley, 1976; Fraker, 1977a, b; Fraker *et al.*, 1979). In Eastern Canada, the major concentrations occur in western Hudson Bay, Cumberland Sound, Lancaster Sound, and Jones Sound (Sergeant and Brodie, 1969, 1975; Brodie, 1971; Sergeant, 1973). Along the western coast of Hudson Bay, the population has been estimated to be approximately ten thousand animals between latitudes 56°N and 61°N, which accounts for one third of the reported population of North America (Sergeant, 1973).

The biological significance of white whale summer concentrations is not known. The hypothesis that the whales used estuaries for feeding was refuted by Sergeant (1973) who observed that a large proportion of whales killed by native hunters had empty stomachs. From this study he hypothesized that whales must use the warm water of estuaries for calving (Sergeant, 1973). Subsequent studies indicated that concentration areas may not be critical to calving (Finley, 1976 Fraker, 1977a, b; Fraker *et al.*, 1979). Finley (1976) found that calving occurred in mid-summer and was protracted over a period of approximately one month. Brodie (1971) estimated that one third of the sexually mature females give birth each year. As females comprise approximately 20% of the native and commercial white whale harvests, and as hunting was most intensive in the concentration area during the calving season, the assumption was made that gravid females should occur in large numbers in the harvest (Fraker, 1977a, b; Fraker *et al.*, 1979). Subsequent research indicated that the incidence of pregnant females sampled was minimal (Fraker, 1977a, b; Fraker *et al.*, 1979). Neonates have been observed offshore prior to arriving at the concentration area (Finley, 1976). The hypothesis that the estuaries are predominantly used as calving areas is inconsistent with these biological findings.

Fraker *et al.* (1977) observed that in the eastern Arctic white whales made use of the estuaries of rivers that were warmed as a result of drainage from plateaus, but not rivers composed of cold meltwater and they subsequently hypothesized that white whales utilized estuaries primarily because there was a thermal advantage to all age classes. The warm estuarine waters may also be important for the summer moult and function as a nursery for neonates (Finley, 1982).

The main objective of this study was to monitor abiotic parameters (temperature, salinity, conductivity, and turbidity) influencing whale abundance in an attempt to identify the factor or factors controlling estuarine use.

Materials and Methods

Study Area

The study was undertaken at the Churchill River estuary, Churchill, Manitoba, Canada (latitude 58°47′N, longitude 94°12′W) located on the western shore of Hudson Bay (Fig. 1). Ice cover in this region is continuous for 7 to 8 months of the year and break-up occurs from early June to early July, while freeze-up occurs from early to

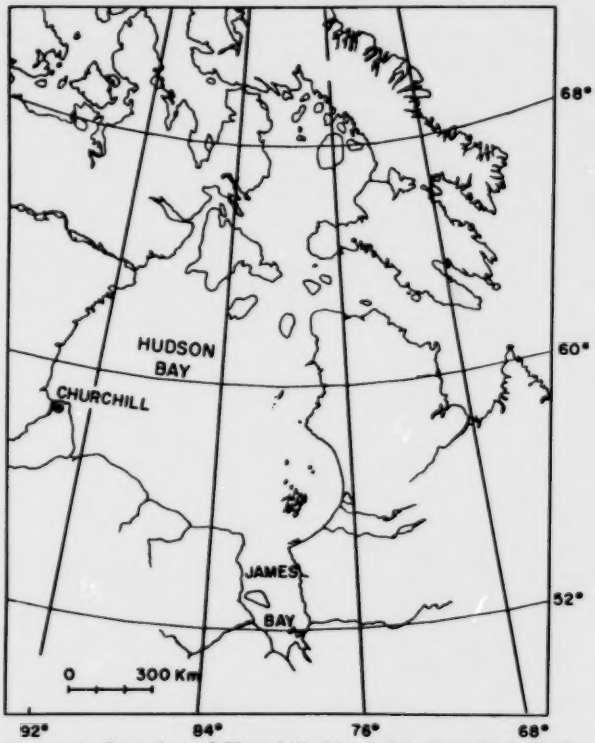


Figure 1. Location of Churchill, Manitoba, Canada (latitude 58°47′N, longitude 94°12′W).

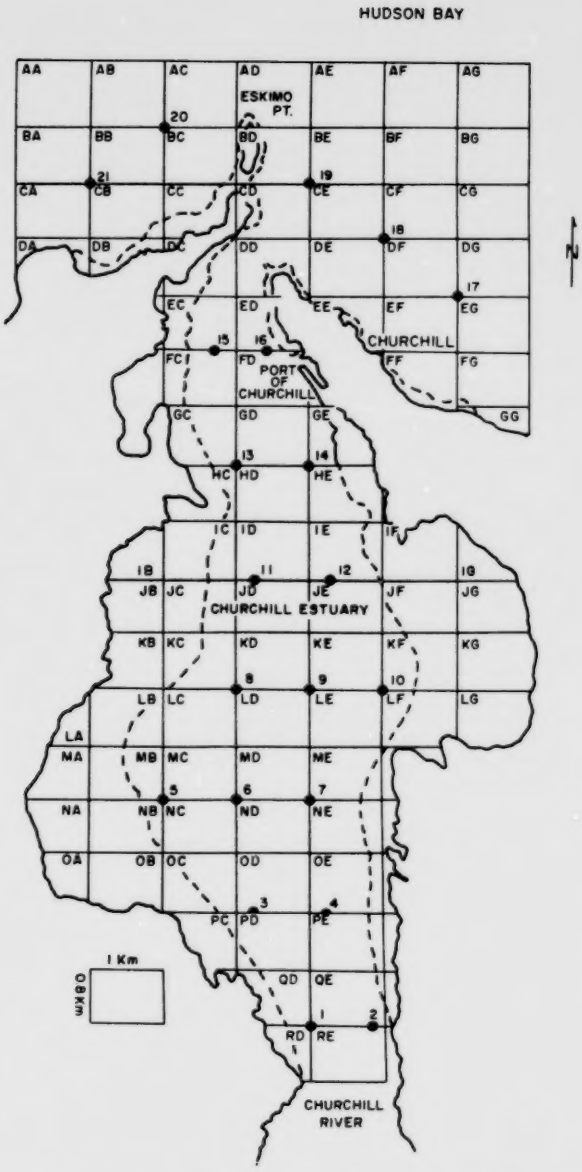


Figure 2. Study area of the Churchill River estuary indicating the grid system used to identify whale distribution and the sampling stations (dots) for water analysis.

mid-November. Tidal amplitude in the estuary is relatively high, from 4.3 m for spring tides to 3.4 for neap tides (Harbours Board Canada, 1980).

Oceanographic Survey

A systematic sampling grid was established in the Churchill River estuary to obtain data on the abiotic parameters associated with the estuarine and coastal waters (Fig. 2). Twenty-one water sampling stations were established using shore markers for each east–west and north–south transect line (Fig. 2). Plastic buoys were also used to identify some sites.

A water survey was conducted by boat at high tide every four days during the summers of 1982 to 1986. The high tide closest to 1200 hours (Central Daylight Saving Time) was chosen to optimize light conditions. In order that all water stations could be sampled the survey was initiated three hours before high tide. The water stations were sampled in decreasing numerical order. All parameters were measured at each station at a water depth of 10 cm and 3 m or the lowest depth in water shallower than 3 m. As weather and/or tide height influenced the water conditions at stations 1 and 2, readings were also taken where the Churchill River entered the estuary (Fig. 2). Station 20 and 21 were used to approximate the coastal water conditions. Water conditions were also surveyed 1 to 5 km north of this site to confirm the coastal situation. A YSI Model 33 S-C-T Meter (Yellow Springs Instrument Co., Inc.) was used to measure temperature, conductivity, and salinity. A DR-EL/2 Spectrophotometer (Hach Chemical Company) was used for turbidity determinations.

Aerial Whale Survey

Whale numbers and location were determined by means of aerial surveys conducted one hour before high tide during each oceanographic survey. Flights were of one hour duration at 1000 ft (305 m) at an average air speed of 100 mph in either a Cessna 185 or 206. When cloud cover was low flights were at 800 to 1000 ft. A preliminary pass over the study site located the whales, and then each distribution area was circled and the number of whales counted with the use of a hand counter. Areas were broken down into smaller blocks if their number and distribution were too extensive to permit accurate counting; or if flights were subject to glare which occurred in early morning or late evening under sunny conditions. The extent of each distribution area was mapped and the number of whales recorded. Aerial surveys were not flown at wind speeds in excess of 15 km or under poor weather conditions. Cancelled aerial surveys were undertaken

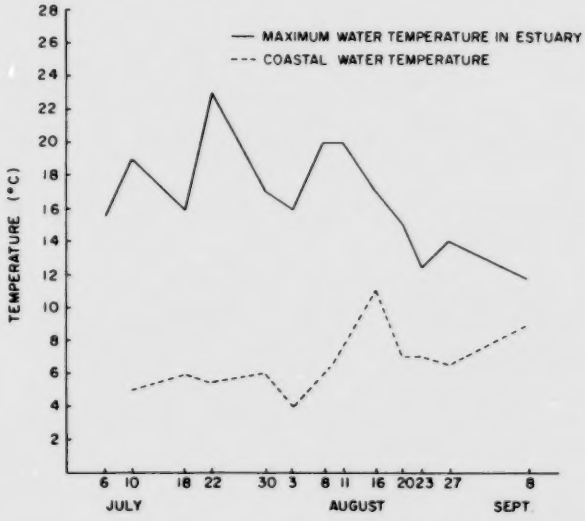


Figure 3. Maximum water temperature for the Churchill River estuary and the coastal water temperature recorded during each water survey date, 1983.

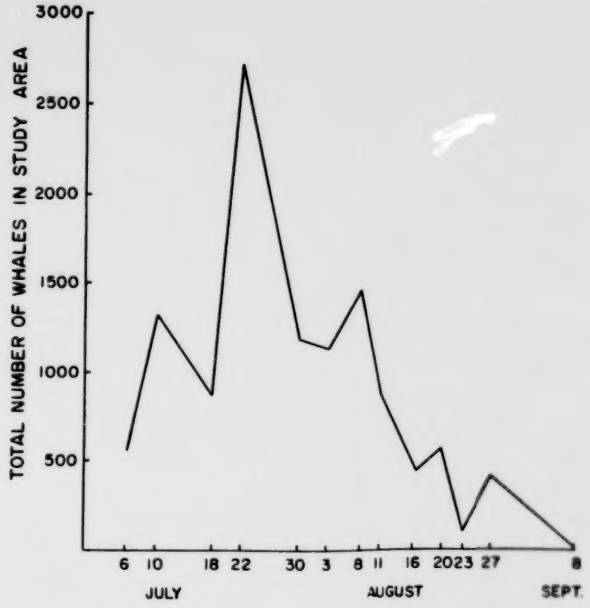


Figure 4. Seasonal changes in white whale abundance in the Churchill River estuary during 1983. Dates represent times of aerial surveys.

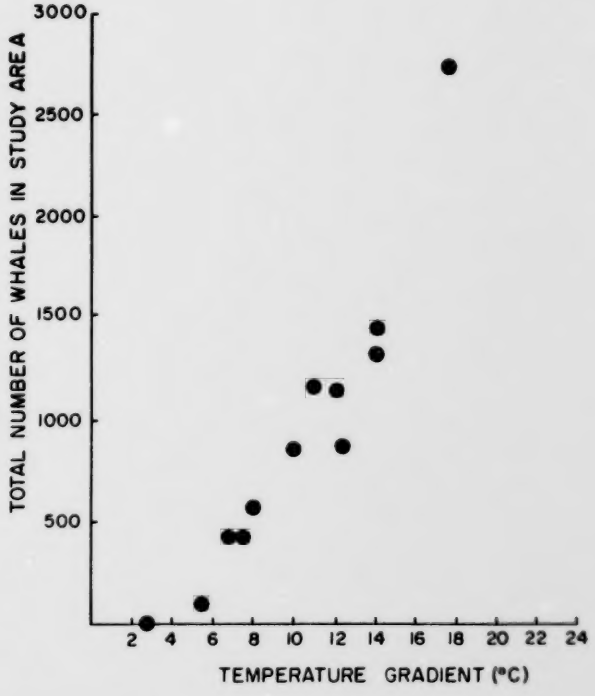


Figure 5. The temperature gradient (the difference between the maximum estuarine and coastal water temperature) plotted against total white whale numbers at the Churchill River estuary study site. Temperature data were obtained by a water survey conducted simultaneously with an aerial survey to count whale numbers.

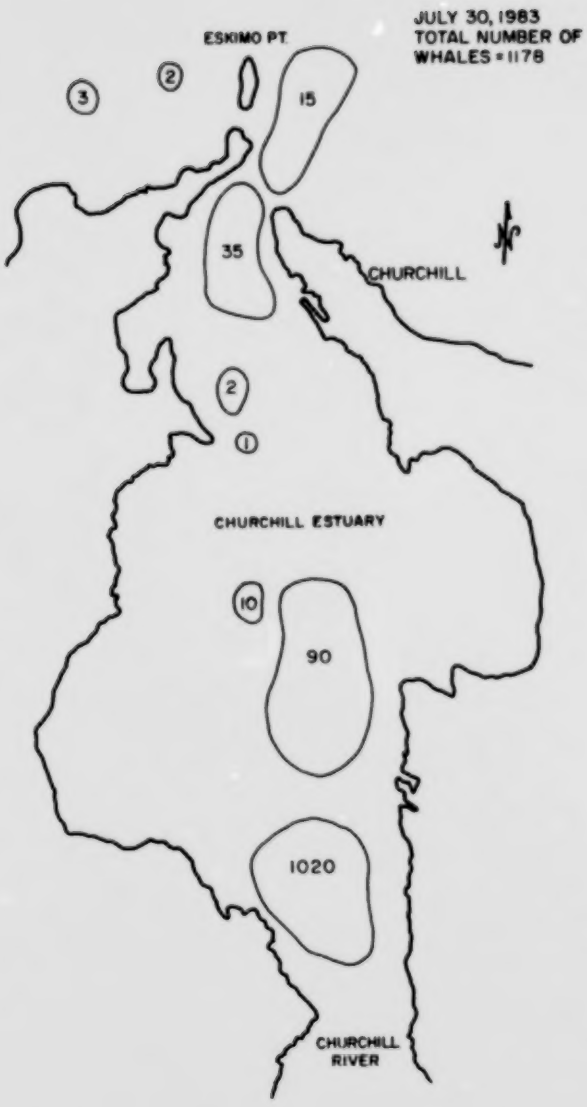


Figure 6. Concentration areas for white whales in the Churchill River estuary from an aerial survey flight on 30 July, 1983. Total number of whales in each area are indicated.

on the next suitable day in conjunction with a water survey. In 1983 low turbidity in the waters of the Churchill Estuary increased the possibility of counting submerged whales. The weather conditions during all surveys were obtained from Environment Canada.

Results

The data presented are preliminary and are limited to the 1983 field season. Water conditions and whale abundance were studied from 6 July and 8 September. The maximum estuarine water temperature, and coastal water temperatures for each survey date are shown (Fig. 3). Estuarine water temperature increased gradually to a maximum of 23°C on 22 July, after which it declined. The warmest temperatures

generally occurred in quadrants RD and RE (Fig. 2). Coastal water temperature increased slightly to a maximum of 11°C on the 16th of August.

The total number of whales occupying the study area at each survey date is shown (Fig. 4). Few whales were observed in the estuary at the beginning of the season (6 July). Numbers increased rapidly and peaked on 22 July when 2735 whales were present. Subsequently, numbers declined gradually until 8 September when no whales remained in the estuary.

The data indicate a very high positive correlation between whale numbers and temperature gradient (the difference between the maximum estuarine and coastal water temperature) (Fig. 5). Large aggregates of whales were also found in the warmest part of the study area at the head of the estuary (Fig. 6). Analysis of the other parameters studied is in progress and is not available at this time.

Discussion

The data indicate (1) that whale abundance in the estuary changes with season (Fig. 4) and is maximal near the end of July; (2) that estuarine water temperatures are consistently higher, but are less stable, than those of the coastal waters for most of the summer ice-free season (Fig. 3); and, (3) that total whale numbers in the estuary are highly correlated with the temperature gradient between the estuary and the coast rather than the actual estuarine temperatures (Fig. 5).

Fraker *et al.* (1979) conducted a pilot study in the Mackenzie River estuary and concluded that warm water temperature appeared to be the major factor influencing white whale distribution. In his study the data base was small and no attempt was made to monitor the temperature gradient between the coastal waters and the estuary.

In the present study, the data indicate that the temperature difference is an important environmental cue that stimulates whale movement into the estuaries. The size of whale aggregates also appears to be influenced by high temperature areas (Fig. 6). Thus the hypothesis of Fraker *et al.* (1977), that white whales use estuaries for thermal advantage appears to be upheld by these results; however, the details of exactly what the thermal advantage is remains unclear, and other cues may be important in influencing whale behaviour.

Acknowledgments

The authors gratefully acknowledge the support of the World Wildlife Fund of Canada and especially thank Mr. M. Hummel, the Executive Director, for his continued support and encouragement. We also thank Mr. C. Blomme, Barb Draper, Mr. P.D. Idle, Mr. D. Webber, and Mr. A.E. Wokes for their technical support.

References

Brodie, P.F. 1971. A reconsideration of aspects of growth, reproduction, and behavior of the white whale (*Delphinapterus leucas*), with reference to the Cumberland Sound, Baffin Island, population. Journal of Fisheries Research Board of Canada, 28:1309–1318.

Finley, K.J. 1976. Studies of the status of marine mammals in the central district of Franklin, N.W.T.: June–August, 1975. Report prepared for the Polar Gas Project by LGL., Toronto, Ontario. 183 p.

Finley, K.J. 1982. The estuarine habit of the beluga or white whale *Delphinapterus leucas*. Cetus 4 (2):4–5.

Fraker, M.A. 1977a. The 1976 white whale monitoring program, Mackenzie Estuary, N.W.T. Prepared for Imperial Oil Limited, Calgary, by F.F. Slaney & Company Limited, Vancouver, B.C. 73 p.

Fraker, M.A. 1977b. The 1977 white whale monitoring program, Mackenzie Estuary, N.W.T. Prepared for Imperial Oil Limited, Calgary, by F.F. Slaney & Company Limited, Vancouver, B.C. 53 p.

Fraker, M.A., Gordon, C.D., McDonald, J.W., Ford, J.K.B., and Cambers, G. 1979. White whale (*Delphinapterus leucas*) distribution and abundance and the relationship to physical and chemical characteristics of the Mackenzie estuary. Canada, Fisheries and Marine Service Technical Report. 863:v' 56 p.

Fraker, M.A., Sergeant, D.E., and Hoek, W. 1977. Bowhead and white whales in the southern Beaufort Sea. Beaufort Sea Project Technical Report No. 4, Department of Fisheries and the Environment, Victoria, B.C. 128 pp.

Harbours Board Canada. 1980. Port Directory.

Sergeant, D.E. 1973. Biology of white whale (*Delphinapterus leucas*) in western Hudson Bay. Journal of Fisheries Research Board of Canada. 30:1065–1090.

Sergeant, D.E., and Brodie, P.F. 1969. Body size in white whales, *Delphinapterus leucas*. Journal of Fisheries Research Board of Canada. 26:2561–2580.

Sergeant, D.E., and Brodie, P.F. 1975. Identity, abundance, and present status of populations of white whales, *Delphinapterus leucas*, in North America. Journal of Fisheries Research Board of Canada. 32:1047–1054.

HABITAT TOLERANCE OF *DRYAS INTEGRIFOLIA* FROM STUDIES NEAR CHURCHILL, MANITOBA AND ALEXANDRA FIORD, ELLESMERE ISLAND, N.W.T.

Gordon T. Hart

Department of Botany, Erindale College, University of Toronto, Mississauga, Ontario L5L 1C6

Level: Master's

Abstract

Dryas integrifolia M. Vahl (Rosaceae) is a cushion shrub common throughout the Canadian barrens. It is ubiquitous across a spectrum of habitats unequalled by other arctic species. Sixteen habitats of this species, representing as many distinct plant communities, were studied to derive the range of physical parameters which *D. integrifolia* tolerates. The habitats were located at Akudlik, Manitoba (59°N) and in the lowlands at Alexandra Fiord, NWT (79°N) — a low-arctic and a high-arctic location. At Alexandra Fiord, *D. integrifolia* is present in all terrestrial habitats, excluding only the beach and ponds. The habitat spectrum at Akudlik is narrower, as *D. integrifolia* is absent from the most hydric

habitats and has poor success under forest or shrub canopy. This restricts the species's range to the mesic and xeric tundra habitats. There is no strict altitude limit, as *D. integrifolia* is present from sea level to the tops of mountain plateaux in the eastern Canadian Arctic. Growing season degree days (above 0°C) ranged from 261 to 1002. Late snowbed plants had as little as 45 days to set fruit, and those in exposed xeric habitats up to 90 days. The habitats' soil pHs ranged from 5.1 to 8.0. *D. integrifolia* grew in mineral soils derived both from granitic and dolomitic parent material. In established tundra it often grew in the thick litter layer. Out of 109 species recorded in the plant communities with *D. integrifolia*, not one occurred in every habitat as *Dryas* did.

Key words: *Dryas integrifolia*, Alexandra Fiord, Akudlik.

Résumé

Dryas integrifolia est un arbuste commun dans tout l'Arctique canadien. Cette espèce est unique pour sa tolérance à une grande variété d'habitats. Seize habitats de *D. integrifolia* représentant un nombre égal de communautés ont été étudiés, afin d'indiquer la variété d'habitats associée à cette espèce. Les habitats étudiés sont situés à Akudlik, Manitoba (59°N), et à Alexandra Fiord, T.N.O. (79°N) respectivement dans le Bas-Arctique et dans le Haut-Arctique. À Alexandra Fiord, *D. integrifolia* était rencontré dans tous les habitats terrestres sauf les milieux littoraux et les mares. À Akudlik la diversité d'habitats pour *D. integrifolia* est moindre. Cette Rosacée n'a pas été observée dans les milieux hydriques et sa vitalité dans une communauté arbustive ou arborescente était reduite, ce qui restreint la distribution de cette espèce aux toundras mésiques et xériques. Aucune limite altitudinale fût notée pour *D. integrifolia*; dans la zone arctique orientale du Canada, ce taxon est présent dans un variété de situations topographiques, des zones littorales aux sommets de plateaux. Dans la saison de croissance le nombre de degré-jours (au-dessus de 0°C) varie de 261 à 1002. Les plantes se développant dans les congères (à déneigement tardif) avaient aussi peu que 45 jours pour produire leur fruits et ceux des habitats xériques exposés disposaient de 90 jours. Le pH des habitats examinés varie entre 5.1 et 8.0. *D. integrifolia* croît sur des sols minéraux développés à partir de matériaux granitiques ou dolomitiques. Dans les milieux arctiques où la végétation est continue ce taxon croît à l'intérieur d'une épaisse couche de litière. Parmi les 109 espèces vasculaires échantillonées dans 16 communautés, *D. integrifolia* possède la plus haute fréquence d'observation.

Mots-clés: *Dryas integrifolia*, fiord Alexandra, Akudlik.

Introduction

Dryas integrifolia M. Vahl (Rosaceae) is known by the common names arctic avens or dryade à feuille entière. It is a ubiquitous chamaephytic evergreen shrub of arctic Canada. It grows throughout northern North America above the treeline (Simmons, 1913; Polunin, 1940; Porsild, 1947; Böcher, 1963; Scoggan, 1978; Porsild and Cody, 1980; Bridgland and Gillett, 1983), and from northernmost Greenland (Polunin, 1940; Holmen, 1957; Böcher *et al.*, 1968) across to the Chukotka Peninsula in northeastern Asia (Kozhevnikov, 1979). It follows the treeline south in the Cordillera and the Laurentians. There are also disjunct colonies in Ouimette Canyon near Thunder Bay, and on Slate Island in northern Lake Superior near Schreiber (Scoggan, 1978). Citations of specimens from forested areas are doubtful (*eg.* specimen from Flin Flon, Manitoba cited in Scoggan, 1978), so the treeline appears to form a clear boundary to the species's range.

D. integrifolia is reported to be a calcicole, as are all the other members of its genus (Fernald, 1907; Kozhevnikov, 1979; Porsild and Cody, 1980). Nevertheless, it was found to have existed on soil with markedly low concentrations of calcium and magnesium (Tolonen and Tolonen, 1984). Spatt (1983) found *D. integrifolia* growing in acid *Sphagnum* peat. Böcher (1963) reports that it often dominates plant communities on soil with pH less than 5. Simmons (1906) describes it as common on both limestone and granite parent material on Ellesmere Island.

This species is often a pioneer in disturbed habitats. Such agents as deglaciation (Porsild, 1947), frost-heaving (Rune, 1954), shifting river channels (Scoggan, 1950; Murray, 1978), sand deposition (Peterson and Billings, 1980), and den excavation (Garrott *et al.*, 1983) provide fresh sites for *D. integrifolia* to colonize. It was also present in 23 of 33 established habitats investigated by Böcher (1963) in Greenland, representing a wide range of conditions. Thus, it shows a tolerance for a great range of physical conditions in the arctic. In spite of this, it has been suggested that *D. integrifolia* may not be able to successfully compete with other species where vegetative cover reaches 100% (Rune, 1954; Given and Soper, 1981).

The focus of this investigation was to determine the range of habitats which are occupied by *D. integrifolia* at a high arctic (Alexandra Fiord, NWT) and a low arctic (Akudlik, Manitoba) locality. Climate of the respective localities, plus habitat moisture regimes, microclimates, soils, and plant communities were examined to quantify the habitat diversity.

The Alexandra Fiord lowland (78°54′N, 75°50′W) is midway up the east coast of Ellesmere Island in the Northwest Territories of Canada. A disused RCMP post, on the south shore of the fjord, served as our research base from 13 June to 30 August 1984. The lowland stretches south from the basecamp and is a deglaciated valley bordered by steep cliffs to east and west. It rises gradually to two glacier tongues at the south end which feed several streams. The valley offers a varied surface, and outcrops of dolomites and granite are present. The combination of these features creates a thermal and hydric oasis in which arctic biota flourish, when compared to the surrounding arctic desert. Ten distinct habitats, each containing *D. integrifolia* but not necessarily as a dominant in the plant community, were chosen as the sites for studies at Alexandra Fiord.

Akudlik (58°45′N, 94°07′W) is three miles south of the port of Churchill, Manitoba. It was the location, until the end of 1985, of the Churchill Northern Studies Centre which served as our base from 7 June to 23 August 1985. It is adjacent to seacoast, tundra, and treeline habitats. Both limestones of the Hudson Bay lowlands, and acidic rock of the Canadian Shield, outcrop nearby. The area is relatively flat, and still in the process of isostatic rebound following the retreat of the continental glacier. Six habitats were chosen for study at Akudlik, in the same way as at Alexandra Fiord.

Methods

Climate

Daily air temperatures have been collected through the field season at Alexandra Fiord for several years using a Campbell Scientific CR-21 datalogger with peripheral thermistors. These were used to locate a homoclime at which complete weather records were available. Eureka, NWT (a weather station) is a homoclime for Alexandra Fiord, and so thirty year averages for monthly air temperature and precipitation were obtained from Eureka for Alexandra Fiord, and from Churchill airport for Akudlik (Atmospheric Environment Service, 1982a, 1982b). Solar radiation was measured at both field stations during the field season using a Weather Measure Corporation R401 actinograph. These data are provided to show the general climatic features in each of the research locations, and may be regarded as uniform for all of the habitats within each location.

Moisture Regime

At intervals of one or two weeks, paired soil moisture samples were collected at each study habitat. Soil samples were taken at the surface to a depth of 5 cm with a circular coring can of 275 cc volume. After fresh weight determination, the samples were dried over an oil-combustion heater at Alexandra Fiord, or in an electric drying oven at Akudlik. The constant dried weight of the samples was determined, and soil moisture contents per oven-dried weight, and per volume, were calculated. These values were graphed for each study habitat, and analysis of the diagrams helped to classify the habitats into moisture regimes.

Microclimate

During the first few days of the two field seasons, survey walks were conducted in each study habitat at intervals, to determine the date at which snowcover melted. A limited number of habitats was chosen at this time for measurement of microclimate, which is time-intensive. Three habitats were chosen at Alexandra Fiord to represent a hydric, mesic, and xeric moisture regime. At Akudlik, four were chosen to represent hydric, mesic, and xeric tundra habitats, and a mesic forest edge habitat.

Average temperature at ground surface was measured by the Pallmann dextrose inversion technique (Pallmann *et al.*, 1940), using the "rapid inversion solution" as given in Berthet (1959). Dextrose syrup, in an equal volume of acid buffer solution, is gradually hydrolyzed into fructose and glucose. The reaction is thermodependent, *ie*. low temperature causes dextrose to invert slowly, and greater temperature causes more rapid inversion. An optical polarimeter determines the rate of inversion by measuring changes to the angle of rotation of the dextrose optical plane when polarized light is passed through the solution. The Pallmann probes consisted of disposable plastic scintillation vials filled with 10 ml of the combined solution. A cohort of probes was buried just beneath the soil surface, and at five day intervals two probes were removed at each habitat to measure angle of rotation on the polarimeter. A regression relating rate of change in the angle of rotation in the field solutions to average temperature was generated for each year's solution. From these average temperatures, the number of degree days (above 0°C) over the field season was derived.

The vertical microthermal profiles of the study habitats were measured by copper-constantan thermocouples. These were shaded by vertical white cardboard cylinders aboveground, to allow exposure to the air without exposure to the sun. Temperature profiles were recorded every three days at solar noon. The stations were always visted all on the same day in the same order. The diurnal pattern of temperature variation was recorded at each location once, for a 24-hour period on a sunny day. Microvolt readings were taken using a Wescor MJ55 psychrometric microvoltmeter with a zero junction. The readings were converted to degrees Celsius from a table giving the corresponding values.

Soils

Separate textural and nutrient tests were conducted on each soil horizon sampled. The technique of textural analysis depended on the nature of the sample. First, a modified dry combustion method (MacDonald, 1972) was used to determine the organic content. Small samples (1–5 g) of the oven-dried soil were weighed, heated to 550°C in a muffle furnace for a period of 40 minutes (repeated if charcoal still present), then reweighed to measure the loss-on-ignition. Mechanical analysis of mineral soil samples was by hydrometry of a soil suspension (MacDonald, 1972). Samples of organic horizons were not tested in this way, since they have an insignificant mineral component. Nutrient analyses were carried out at Agri-Food Laboratories, Guelph, Ontario, for pH and levels of Ca, Mg, K, P, and total salts.

Community structure

In each *D. integrifolia* study habitat, the community of plants was surveyed by the use of ecological quadrats (5*5dm aluminium frames divided into grids of 100 squares by monofilament). Twenty random quadrat placements were made within each habitat study area. A table of random digits was used to dictate the number and direction of paces between quadrat placements. Each vascular plant species was identified and its cover estimated.

Results and discussion

Figures 1 and 2 are graphic representations of the general climatic features at both research locations. Average yearly climatic data for locations where the long-lived *D. integrifolia* is found are useful indicators of its long-term environment. These two locations differ in the amount of precipitation, and the length of the potential growing season. The high-arctic station shows a short drought period in June, contrasting with Akudlik which is moist throughout the year. Also, the period of the year with temperatures warm enough to allow vigorous growth is approximately twice as long at the latter. The mean temperature at Akudlik is about 10° greater than at Alexandra Fiord. Summer temperatures at Eureka reach around 8.4° in July, with a recorded extreme of 19°. Comparable figures from Akudlik are 17° and 34° respectively. The climates of the two locations thus differ significantly within the limits of their arctic positions, and the climate at Akudlik may be said to be the more benign.

In the process of choosing study habitats, distribution of *D. integrifolia* throughout each location was observed. At Alexandra Fiord, it grew in all of the terrestrial habitats from the lowland to the tops of the adjacent plateaux, excepting

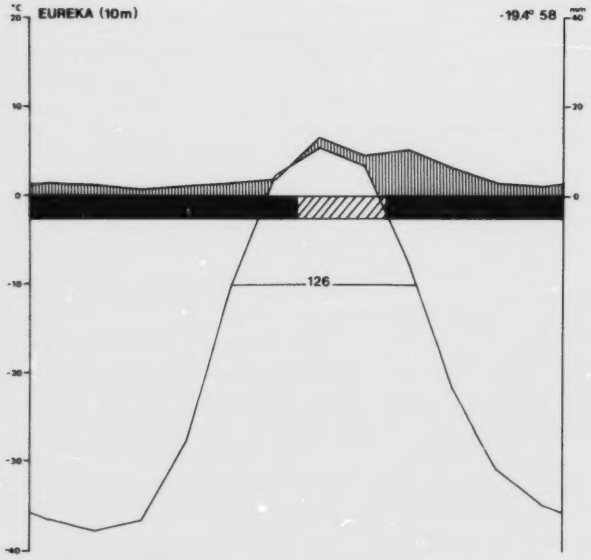


Figure 1. Ecological climate diagram (*sensu* Walter, 1979) for a weather station with climate similar to Alexandra Fiord. Horizontal axis represents the year from January to December. Information across the top includes: station name, altitude, mean annual temperature, and mean annual precipitation. Vertical shading indicates relatively humid conditions, diagonal shading indicates months with absolute minimum temperature below 0°, and black shading indicates months with mean daily minimum below 0°. Number of days with mean temperature above −10° is given.

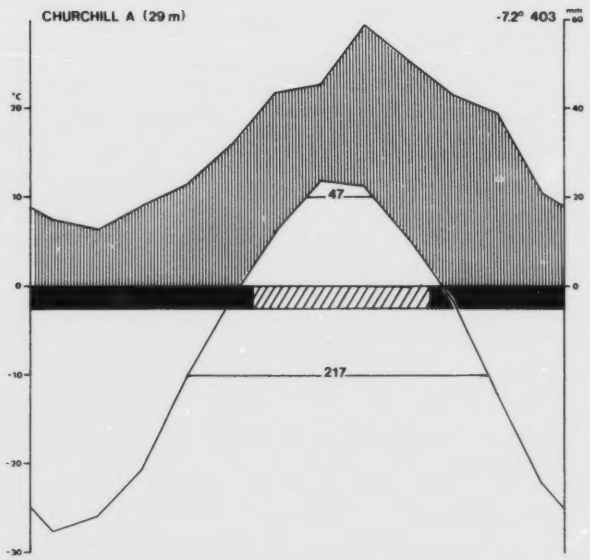


Figure 2. Ecological climate diagram for weather station adjacent to Akudlik. Information is as given beneath Figure 1, and includes number of days with mean temperature above +10°.

only ponds and the seacoast. At Akudlik, the seacoast had *Dryas* habitat, but not the most hydric meadows and ponds, nor the forest. General descriptions of each of the study habitats are given below. Names of the form (A_) indicate habitats at Alexandra Fiord; those of the form (C_) are at Akudlik. The list of habitats at each location is given according to moisture regime, from driest to wettest. Soil types are designated by the Canadian System of Soil Classification (CSSC, 1978).

AA – A xeric cliff margin, overlooking a cut-in river channel at a height of 5 m, very well-drained. Snowfree 10 June. Parent material is dolomitic limestone outcrop, overlain by angular gravelly compact regosolic static cryosol. Vegetative cover is 36%, primarily *D. integrifolia* (10%), *Salix arctica*, and lichens, in isolated clumps. The habitat slops NNW at 3%.

AB – A xeric raised portion of the general ground moraine, snowfree 12 June. The soil is very well-drained, stony, and weathered so that the exposed stones are sharpened around harder contained particles of chert. This is a cherty regosolic static cryosol. Vegetation is sparse (28% cover), with clusters of *D. integrifolia* (16%), *Saxifraga oppositifolia*, and lichens. Slope is to the NNE at 2%.

AC – A xeric disturbed habitat occupying the verge of a rough landing strip for airplanes, snowfree 14 June. The soil is regosolic static cryosol. It is sandy and unstable, except where vegetative clusters (covering 37%) create stable hummocks. *D. integrifolia* (13%) and lichen are codominant. Slope is NNE at 4%.

AD – A xeric-mesic, late snowbed hillslope, snowfree 27 June. The soil is a stony regosolic static cryosol. Sometimes an Ah horizon is found. Plant cover (73%) is scattered at the top of the slope, but covers more ground towards the bottom. It forms a lichen-*Cassiope tetragona* heath. *Dryas* cover is 7%. Slope is NNE at 36%.

AE – A xeric-mesic streambank, snowfree 13 June. The soil is slightly stony, orange-mottled, and vertically layered. These combine to make the soil a cobbly gleyed cumulic regosol. Plant cover (99.5%) is dominated by *D. integrifolia* (57%) and *Salix arctica*, with mosses and lichens both present. Slope is 3% to the NE.

AF – A very stony mesic scree slope against the western plateau, snowfree 19 June. Drainage is moderate, with both ground and surface flow. The soil represents a cumulic regosol with angular gravel, cobbles, and boulders. Vegetation (59%) is patchy on the sides of ground irregularities. There is an unusual mix of *D. integrifolia* (22%), *Salix arctica*, *Saxifraga oppositifolia*, and *Eriophorum gracile*. Elevation is about 100 m, and slope is 32% to the N.

AG – A mesic *Cassiope* heath on mineral soil, snowfree 14 June. Some stones are present, but vegetative cover is 98.5%. The aspect is hummocky and shallowly drained. The soil is a brunisolic static cryosol, due to the presence of a Bm horizon greater than 10 cm thick. *D. integrifolia* (23%) and lichen are subdominant. Slope is a minimal 2% to the N.

AH - A mesic-hydric and very rocky concave slope, snowfree 16 June. The area is seep-irrigated due to its position at the base of the western plateau, and imperfectly drained. Movement of the large rocks and ice has distorted the soil horizons, producing an exceedingly rocky regosolic turbic cryosol. The vegetated patches (73% cover) nestle amongst the exposed boulders and granitic bedrock. *D. integrifolia* (25%) and *Cassiope* are codominant. This habitat slopes at 13% to the ENE.

AI - A hydric sedge meadow on a saddle-back ridge below the western plateau, snowfree 14 June. The soil has thick litter overlying the mineral stratum, and is free of stones. Standing water is often present. A Cg horizon (dull grey-brown as opposed to light yellow-brown) makes this a gleysolic static cryosol. Vegetation (89% cover) is low-hummocky, and the hollows where standing water collects are usually lined only with dead moss. *D. integrifolia* (42%) is dominant, with *Carex misandra*, *C. atrofusca*, *Eriophorum angustifolium*, and moss. Slope is 12% to the N.

AJ - A lowland hummocky sedge meadow, snowfree 15 June. Drainage is very poor here, with standing water most of the time. The mineral contact is under substantial humic organic material in this habitat, and the pedon represents a terric humic organic cryosol. Vegetation (76% cover) is restricted to the hummocks, and is dominated by *D. integrifolia* (28%), *Eriophorum angustifolium*, and *Carex membranacea*. Slope is 4% to the NNW.

CK - A xeric sandy road verge. The soil is a gravelly anthropogenic orthic regosol, as it is influenced by the construction of the roadbed. Drainage is rapid. Plant cover (53%) occurs in patches, often surrounding *D. integrifolia* mats (40%) or legumes such as *Hedysarum alpinum* or *Oxytropis campestris*. Slope is 8% to the SSW.

CL - A xeric-mesic slope on an old (>25 years) clay embankment. The soil is a gravelly orthic regosol, unusually clay-rich for this area. The general vegetation covers 98% of the ground, and reaches a heighth of 4dm. *D. integrifolia* (9%) grew under this *Salix brachycarpa* and *Hedysarum* canopy in small irregular mats. Slope is 30% to the N.

CM - A mesic forest edge habitat adjacent mile 507 on the Hudson Bay Railway line. The soil is a regosolic static cryosol. This habitat has the greatest degree of shading of *D. integrifolia* (6% cover) by taller plants, and the growth form is reduced to creeping stems rather than established mats or cushions. Plant cover is total, with *Vaccinium uliginosum* dominant and a 4–5 m overstorey of *Picea glauca* and *Larix laricina*, on level ground.

CN - A mesic dolomitic gravel marine beach. *D. integrifolia* is found just above the strand line. The soil is angular cobbly and gravelly, a sorted beach deposit which has formed an orthic static crysol. Plant cover is 57%, and thin litter covers the soil except on some protruding rocks. The dominant species is *Salix reticulata*. *D. integrifolia* cover is 6%. The slope is 6% to the E.

CO - A mesic hummocky tundra heath upon flaggy limestone plates. The soil is an orthic static cryosol, with 5 to 10 cm moss and lichen litter. Lichen (mainly white *Cladonia* spp.) is dominant, and the result is a high surface albedo. Plant cover is 87%, and *D. integrifolia* covers 33%. Slopes is 4% to the NW.

CP - A hydric hummocky sedge meadow with thick mossy organic soil. This habitat is adjacent to habitat CO. The soil is fibric organic cryosol. *D. integrifolia* (6% cover) grows only on the hummocks. The floristics of this site are complex as many species are roughly equal in cover. Vegetative cover is 50%, and standing water occupies the hollows for much of the season.

Upon arrival at Akudlik on 7 June, we found that snowcover was not present in most *D. integrifolia* habitats. Furthermore, local residents indicated that there had been little snow that year and it had mostly accumulated in scattered drifts. It will be assumed that the influence of snowcover on initiation of growth by *D. integrifolia* does not vary significantly at Akudlik.

Temperature conditions at ground level are given in Table 1 for a selection of habitats. Solar radiation differs little in amount between the two locations (77.53 $Kw \cdot m^{-2}$ over 77 days at Alexandra Fiord, and 73.05 $Kw \cdot m^{-2}$ over 75 days at Akudlik), but it is virtually continuous at Alexandra Fiord and diurnal at Akudlik. Degree days vary greatly among habitats. The xeric habitats both have the highest degree day totals in their respective locations, up to twice the totals at more hydric habitats. Habitats at Alexandra Fiord reach only half the degree days attained by habitats with similar moisture regimes at Akudlik.

Table 2 gives the varying times of fruiting exhibited by *D. integrifolia* in different habitats. Fruiting periods and their success appear to be related to the moisture regime of the habitats, with the xeric regimes having the most prolonged and (perhaps) earliest fruition. Fruition period in hydric regimes is much shorter. In Akudlik, the success of fruition in hydric stands is reduced. If snowcover melting dates are examined at this point, it will be seen that the plants in the late snowbed (*eg.* AD) have delayed development and their success also may be reduced because of this.

Edaphic data for the habitats are contained in Tables 3 and 4. The texture of the mineral soils is quite coarse overall, but this is characteristic of soils derived from moraines. Loamy soils are present at AE, AJ, and CL, with relatively high clay content. *D. integrifolia* has been named as a colonizer of river gravels (Scoggan, 1950; Murray, 1978) and is found in an alluvial situation here at habitat AE. The present study also has examples of *Dryas* in thick mossy litter and organic soils (AH, AI, AJ, CO, CP). The soil pH of the *D. integrifolia* habitats shows a range of reactions from alkaline ($pH > 7.4$) through to acid ($pH < 5.5$). Acid soils of both organic and mineral derivation are found. These latter bely the inference that *D. integrifolia* is a calcicole, since they are not calcareous. The nutrient balance of Ca-Mg-K is of some importance in sandy soils, where these three nutrient cations interfere with each other's availability (Heald, 1965). Ca:Mg ratios from 5:1 to 1:1 are considered

TABLE 1

Habitat	°days	days	T_{0cm}	range	T_{mat}	range
AA	458	66	15.2°	16.3°	15.4°	18.0°
AG	261	63	11.1	12.6	12.3	13.1
AI	294	63	9.2	11.2	15.1	19.0
CK	1002	70	26.4	27.9	28.0	30.9
CM	449	58	19.2	21.5	19.4	20.5
CO	716	70	15.4	15.2	21.8	18.9
CP	494	70	25.5	31.3	20.2	23.6

Degree days and period of measurement, mean temperatures at solar noon and maximum daily temperature range experienced at the ground surface and in Dryas mats during the growing season.

TABLE 2

Habitat	Period of fruit set (August) 01-07	08-14	15-21	22-31	% Success
AA	#	#	#	F	25
AC	#	#	#	F	44
AB		#	#	F	51
AE		#	#	F	34
AF		#	#	F	24
AG		#	#	#	28
AH		#	#	#	55
AI			#	F	33
AJ			#	F	50
AD				#	9
CK	#	#	#	#	67
CL	#	#	#	#	55
CM	#	#	#	#	44
CN	#	#	F		36
CO	#	#	F		17
CP			#F		4

D. integrifolia fruition period in study habitats and percent of successful fruition from buds produced. F=completed fruition.

TABLE 3

Horizons		Particle size distribution % OM.	% Coarse fragments	% Sand	% Silt	% Clay	Texture	Total nutrients (ppm) P	K	Ca	Mg	pH	Total salts
AA	C	3.0	76.6	13.3	6.0	1.1	SL	1	5	98	56	7.5	390
	C	1.1	57.3	37.1	3.5	1.0	S	1	2	51	39	7.7	170
AB	C1	0.5	91.2	6.7	1.0	0.6	LS	1	7	75	57	8.0	230
	C2	0.5	76.9	14.9	7.1	0.6	SL	1	3	70	55	8.0	240
AC	C	4.2	4.4	85.3	4.0	2.1	S	1	3	54	26	7.1	130
	C	2.6	9.7	84.0	0.9	2.8	S	1	4	43	18	6.8	120
AD	C	0.9	54.3	41.9	1.7	1.2	S	1	2	32	13	7.4	60
	Ah	20.0	0	71.1	7.3	1.6	S	1	10	51	30	6.1	210
	C	3.0	16.8	74.7	3.2	2.3	S	1	1	33	18	6.7	60
AE	Ah	22.8	0	32.0	34.0	11.3	L	1	5	53	24	5.4	330
	Cg	5.7	0.4	66.5	23.3	4.1	LS	1	6	31	18	5.2	240
AF	C1	1.1	45.5	50.0	2.4	1.0	S	1	2	48	20	7.1	120
	Ofb	24.8	0		NS		O	1	6	108	60	7.1	570
	C	9.7	30.0	44.4	13.8	2.1	LS	1	3	99	48	7.1	360
AG	LFH	21.7	0		NS		O	1	8	36	19	5.6	190
	C	1.0	18.6	66.2	11.8	2.4	LS	1	3	23	12	5.8	90
	LFH	38.1	0		NS		O	1	7	47	27	5.2	300
	C	2.6	38.5	45.6	10.7	2.6	LS	1	3	36	18	5.1	270
AH	C	3.7	0	50.7	37.6	8.1	SL	1	4	39	24	6.7	70
	Oh	92.1	0		NS		O	1	10	55	44	6.2	240
	C	20.2	0	42.9	28.2	8.6	SL	1	4	50	40	6.3	140
AI	Oh	37.5	0		NS		O	2	13	71	42	6.7	270
	Cg	2.5	2.9	72.2	17.8	4.6	LS	1	2	39	19	6.7	70
	Oh	41.7	0		NS		O	3	16	87	49	6.5	480
	Cg	2.5	1.8	72.8	18.7	4.2	LS	1	2	45	20	6.7	90
AJ	Om	54.2	0		NS		O	1	2	68	35	7.0	140
	Om	67.6	0		NS		O	2	18	90	48	7.2	450
	Ah	34.3	0	30.7	26.2	8.7	L	1	5	81	41	6.8	310

Textural and nutrient analyses for soils collected in the study habitats at Alexandra Fiord. Percentage of organic and mineral fractions given by mass. Total salts given in umhos·cm^{-1}. OM=organic matter, S=sand, SL=sandy-loam, L=loam, LS=loamy-sand, O=organic, NS=not significant.

TABLE 4

Horizons		Particle size distribution (%) OM.	Sand	Silt	Clay	Texture	Total nutrients (ppm) P	K	Ca	Mg	pH	Total salts (umhos/cm)
CK	C	2.0	91.9	4.5	1.6	S	1	1	118	10	7.5	120
	C	2.0	89.5	5.8	2.7	S	1	1	123	11	7.6	170
CL	LFH	59.1		NS		O	4	32	108	30	7.0	340
	C	4.6	52.3	30.2	12.9	SL	1	19	163	25	7.5	280
	LFH	32.3		NS		O	8	53	141	35	6.8	520
	C	6.3	45.7	26.1	21.8	L	1	25	171	25	7.4	320
CM	LFH	39.1		NS		O	5	19	179	77	6.0	1310
	C	5.6	85.7	5.6	3.1	S	1	1	119	45	7.3	430
	LFH	28.2		NS		O	4	28	131	47	6.3	1030
	C	12.5	74.9	8.2	4.4	LS	1	5	135	39	7.3	870
CN	LFH	20.0		NS		O	7	47	134	40	7.0	660
	LFH	17.9		NS		O	5	22	99	42	7.1	460
CO	LFH	50.9		NS		O	5	23	166	55	6.8	1080
	LFH	77.0		NS		O	7	22	122	45	6.3	990
CP	Of	53.3		NS		O	1	25	231	24	7.2	670
	Of	42.4		NS		O	1	21	207	26	7.4	580

Textural and nutrient analyses for soils collected in the study habitats at Akudlik. Percentage of organic and mineral fractions given by mass. OM=organic matter, S=sand, SL=sandy-loam, L=loam, LS=loamy-sand, O=organic, NS=not significant.

TABLE 5

Species	Habitats occupied/16	Alexandra Fiord regime	pH	Ca(ppm)	Akudlik regime	pH	Ca(ppm)
Dryas integrifolia	16	X-H	5.1-8.0	23-108	X-H	6.0-7.6	99-231
Saxifraga oppositifolia	11	X-H	5.1-8.0	23-108	X	7.5-7.6	118-123
Polygonum viviparum	11	XM-H	5.1-7.2	23-108	XM-H	6.0-7.5	99-231
Salix arctica	10	X-H	5.1-8.0	23-108			
Vaccinium uliginosum	8	MH-H	6.2-6.7	23-108	X-H	6.0-7.6	99-231
Cassiope tetragona	7	X-H	5.1-7.7	23-108			
Carex misandra	7	X,M-H	5.1-8.0	23-108			
Salix reticulata	6				X-H	6.0-7.6	99-231
Arctostaphylos alpina	6				X-H	6.0-7.6	99-231
Luzula confusa	5	XM-MH	5.1-7.4	23-108			
Equisetum arvense	5	H	6.8-7.2	68- 90	XM-M	6.3-7.6	99-171
Equisetum variegatum	5				X,M-H	6.0-7.6	99-231
Betula glandulosa	5				XM-H	6.0-7.5	99-231
Rhododendron lapponicum	5				XM-H	6.0-7.5	99-231
Tofieldia pusilla	5				XM-H	6.0-7.5	99-231
Hedysarum alpinum	5				X-M	6.0-7.6	99-179
Carex aquatilis stans	3	H	6.8-7.2	68- 90	M,H	7.0-7.4	99-231

Most common vascular plant species in the study habitat communities, and the range of three physical parameters in the habitats where they are found. X=xeric, M=mesic, H=hydric.

desirable, and the sandy habitats either fall within this range or exceed it. Calcium (a macronutrient required by all plants) is thus present in all habitats, but not always at levels sufficient to justify a calcicole status for *D. integrifolia*. Neither low pH nor low calcium can be related to decreased success by this species.

Certain plant communities appear to have some influence on *D. integrifolia* success in the Low Arctic. Habitat CM, the forest edge, and to a lesser extent habitat CL, produced a different growth pattern in the plant. Rather than forming radial mats or cushions, the stems became decumbent runners, with less branching and scattered leaf formation.

Both of these habitats have phanerophytes which shade *D. integrifolia* and perhaps impede its dissemination. Its cover values are very low in proportion to total cover in habitats of this type, and it is often absent from them. Phanerophyte plant communities may be a factor influencing its southern limit.

Table 5 is a list of the most common vascular species from all the study habitats. None of the other species equalled *D. integrifolia* in the diversity of its habitats based on the parameters given. Some species occurred at both study locations, but were more restricted by moisture regime or soil pH. The species listed include the most common and widespread tundra plants. Few had average cover values which were as uniformly high as those of *D. integrifolia*. It combines the capability to survive in a wide range of physical situations with a prominent cover value, and so forms an integral part of a great many tundra habitats.

Summary

Ten habitats were studied at Alexandra Fiord, and six at Akudlik, to determine the range of conditions in which *D. integrifolia* is encountered. The two locations represent different arctic climates. Microclimate differs greatly between habitats within each location as influenced by the moisture regime. This also exerts an influence on phenometry of *D. integrifolia*, with relatively hot dry habitats having longer seasons. Fruiting success in late snowbed and low-arctic hydric habitats was reduced. The physical state of the study habitat soils with respect to texture, pH, or calcareousness can not be related to the species's success. *Dryas* is affected by the presence of overshadowing phanerophytes in the plant community, and these may limit its range at the treeline. Within the tundra, *D. integrifolia* is prominent due to its tolerance to a wide range of moisture regimes, soil conditions, and plant communities.

References

Atmospheric Environment Service. 1982a. Canadian Climate Normals 1951-1980 Temperature and Precipitation, Volume 2: The North. Ottawa: Atmospheric Environment Service, Environment Canada.

Atmospheric Environment Service. 1982b. Canadian Climate Normals 1951-1980 Temperature and Precipitation, Volume 3: Prairie Provinces. Ottawa: Atmospheric Environment Service, Environment Canada.

Berthet, P. 1959. La mesure écologique de la température par détermination de la vitesse d'inversion du saccharose. Vegetatio 9:197-207.

Böcher, T. W. 1963. Phytogeography of middle west Greenland. Meddelelser om Grønland 148(3):1-289 w/10 plates (1 colour).

Böcher, T.W., Holmen, K. & Jakobsen, K. 1968. The Flora of Greenland. Copenhagen: P. Haase & Son, Publishers.

Bridgland, J. & Gillett, J.M. 1983. Vascular plants of the Hayes Sound region, Ellesmere Island, Northwest Territories. Canadian Field-Naturalist 97(3):279-292.

Canadian Soil Survey Committee, Subcommittee on Soil Classification. 1978. The Canadian System of Soil Classification. Ottawa: Canada Department of Agriculture Publication 1646. Supply and Services Canada. 164 pp.

Fernald, M.L. 1907. The soil preferences of certain alpine and subalpine plants. Rhodora 9(105):149-193.

Garrott, R.A.; Eberhardt, L.E.; Hanson, W.D. 1983. Arctic fox (*Alopex lagopus*) den identification and characteristics in northern Alaska (USA). Canadian Journal of Zoology 61(2):423-426.

Given, D.R. & Soper, J.H. 1981. The Arctic-Alpine Element of the Vascular Flora at Lake Superior. Ottawa: National Museums of Canada, National Museum of Natural Sciences, Publications in Botany 10.

Heald, W.R. 1965. Calcium and Magnesium. In: Black, C.A.; Evans, D.D.; White, J.L.; Ensminger, L.E.; Clark, F.E. Methods of Soil Analysis. Madison, Wisconsin: American Society of Agronomy. pp. 999-1010.

Holmen, K. 1957. The vascular plants of Peary Land, north Greenland. Meddelelser om Grønland 124(9):1-149.

Kozhevnikov, Yu.P. 1979. Investigations in the genus *Dryas* (Rosaceae) in Tschukotsk populations. Botanicheskii Zhurnal 64(4):479-487.

MacDonald, C.C. 1972. Methods of Soil and Tissue Analysis Used in the Analytical Laboratory. Fredericton, New Brunswick: Canadian Forestry Service, Maritimes Forest Research Centre, Information Report M-X-28.

Murray, D.F. 1978. Vegetation, floristics, and phytogeography of northern Alaska. In: Tieszen, L.L. (ed.). Vegetation and Production Ecology of an Alaskan Arctic Tundra. New York: Springer-Verlag, New York, Incorporated.

Pallmann, V.H.; Eichenberger, E.; Hasler, A. 1940. Eine neue Methode der Temperaturmessung bei Ökologischen oder bodenkundlichen Untersuchungen. Berichte der Schweizerischen Botanischen Gesellschaft 50:337-362.

Peterson, K.M. & Billings, W.D. 1980. Tundra vegetational patterns and succession in relation to microtopography near Atkasook, Alaska. Arctic and Alpine Research 12(4):473-482.

Polunin, N. 1940. Botany of the Canadian Eastern Arctic. Ottawa: National Museum of Canada, Bulletin No. 92.

Porsild, A.E. 1947. The genus *Dryas* in North America. Canadian Field-Naturalist 61(6):175-192.

Porsild, A.E. & Cody, W.J. 1980. Vascular Plants of the Continental Northwest Territories, Canada. Ottawa: National Museum of Canada.

Rune, O. 1954. Notes on the flora of the Gaspé Peninsula. Svensk Botanisk Tidskrift 48(1):117-136 + plates.

Scoggan, H.J. 1950. The Flora of Bic and the Gaspé Peninsula, Québec. Ottawa: National Museum of Canada, Bulletin #115.

Scoggan, H.J. 1978. The Flora of Canada. Ottawa: National Museums of Canada, National Museum of Natural Sciences, Publications in Botany #7.

Simmons, H.G. 1906. The vascular plants in the flora of Ellesmereland. Report of the Second Norwegian Arctic Expedition in the "Fram" 1898-1902 1(2):1-197 w/plates.

Simmons, H.G. 1913. A survey of the phytogeography of the arctic American archipelago. Konglige fysiografiska sällskapets i Lund, Handlingar, ny följd, bind 24(19):1-184 w/2 maps.

Spatt, P.D. 1983. *Sphagnum* at Prudhoe Bay, Alaska. Canadian Field-Naturalist 97(1):115-116.

Tolonen, K. & Tolonen, M. 1984. Late-glacial vegetational succession at four coastal sites in northeastern New England: ecological and phytogeographical aspects. Annales Botanici Fennici 21(1):59-77.

Walter, H. 1979. Vegetation of the Earth and Ecological Systems of the Geo-Biosphere, Second Edition. New York: Springer-Verlag New York Incorporated. 274 pp.

THE DISTRIBUTION OF BOWHEAD WHALES (*BALAENA MYSTICETUS*) IN THE SOUTHEAST BEAUFORT SEA JULY–SEPTEMBER, 1984

Lois A. Harwood

Department of Zoology, University of Alberta, Edmonton, Alberta T6G 2E9

and

Gary A. Borstad

G.A. Borstad Ltd., Sidney, B.C.

Level: L. Harwood, Master's

Abstract

Six systematic aerial surveys were conducted over the southeast Beaufort Sea between July 05 and September 18, 1984. The study area extended from the 2 m isobath seaward to a 7-9/10 concentration of pack-ice, and from the Alaska-Yukon border eastward to Cape Bathurst and Franklin Bay. The primary objective of the surveys was to monitor the distribution and relative abundance of bowhead whales (*Balaena mysticetus*) in relation to oil and gas industry activities, and in relation to oceanographic features. The abundance of bowheads generally increased throughout the open water period, from an estimated 300 during early July, to an estimated 1500–2400 during early-mid September. Coincident with this increase was a general shift in bowhead distribution and change in behaviour. In July, the whales were generally solitary and seen far offshore among the pack-ice. By late August and September, bowheads were more typically seen in large groups, and in nearshore waters. Feeding and socializing behaviours were commonly observed in these congregation areas. The congregation areas were located in waters characterized by: vigorous surface circulation, areas of probable upwelling, and at oceanographic fronts marking the seaward edge of the Mackenzie River plume. Such types of oceanographic features are known to concentrate zooplankton in other regions. Congregations of bowheads seen in 1984 are believed to have been responding to prey concentrations, independent of industry activities.

Key words: Beaufort Sea, Franklin Bay, bowhead whale, aerial survey, distribution, abundance, feeding, prey abundance.

Résumé

Les auteurs ont effectué six relevés aériens systématiques des baleines boréales (*Balaena mysticetus*) dans le Sud-Est de la mer de Beaufort, entre le 5 juillet et le 18 septembre 1984. La région étudiée allait de l'isobathe de 2 m près du rivage jusqu'à la banquise chaotique d'une concentration de 7 à 9/10e, et de la frontière entre l'Alaska et le Yukon jusqu'au cap Bathurst et à la baie Franklin à l'Est. L'objectif premier de ce relevé était de connaître la répartition et l'abondance des baleines par rapport aux activités de recherches pétrolière et gazière, et aux particularités océanographiques. En général le nombre des baleines s'est accru au cours de la période d'eaux libres. Il y en avait environ 300 au début de juillet, et ce nombre a atteint entre 1 500 et 2 400 du début à la mi-septembre. Parallèlement à cet accroissement numérique, la répartition des baleines a changé, en général, de même que leur comportement. En juillet, elles restaient solitaires et loin du littoral, parmi la banquise chaotique. À la fin d'août et en septembre, elles se tenaient généralement en larges groupes dans les eaux littorales. Les auteurs ont observé des comportements de recherche de la nourriture et de socialisation dans ces aires de rassemblement, qui étaient caractérisées par une énergique circulation des baleines en surface, des remontées probables d'eaux profondes, et la limite océanique de l'éventail des eaux du Mackenzie. On sait qu'en d'autres régions ces particularités océaniques concentrent le zooplancton. Les auteurs estiment que les rassemblements de baleines boréales observés en 1984 correspondent à des concentrations de la nourriture, indépendamment des activités de recherche d'hydrocarbures.

Mots-clés: Mer de Beaufort, baie de Franklin, baleine boréale, relevé aérien, recherche de nourriture, abondance du plancton.

Introduction

The western Arctic population of bowhead whales (*Balaena mysticetus*) winters among the pack-ice in the Bering Sea, and migrates annually to summering areas in the southeast Beaufort Sea and Amundsen Gulf. From late June through September, a portion of the population occurs in some areas coincident with oil and gas industry exploration activities. The potential effects of these activities on the bowhead population are an area of concern (FEARO 1984). The primary objective of the present study was to monitor the distribution of bowheads relative to industry activities, and to identify relationships between oceanographic features depicted in satellite imagery and observed distribution of whales.

The study was the fifth consecutive year of systematic aerial surveys for bowheads in the southeast Beaufort Sea. Past surveys, reported in Renaud and Davis (1981), Davis *et al.* (1982), Harwood and Ford (1983) and McLaren and Davis (1985), have shown that the late summer distribution of bowheads varies markedly both among and within years. In 1980, the first year in the survey series, the industrial development zone was used extensively by bowheads. The number of whales seen in this area from 1981–83 was considerably lower. Two alternate (but not necessarily exclusive) hypotheses have been formulated to explain the observed differences in bowhead distributions (LGL *et al.* 1984):

— industrial activity has caused, or contributed to, a progressive exclusion of bowheads from the development zone, and,

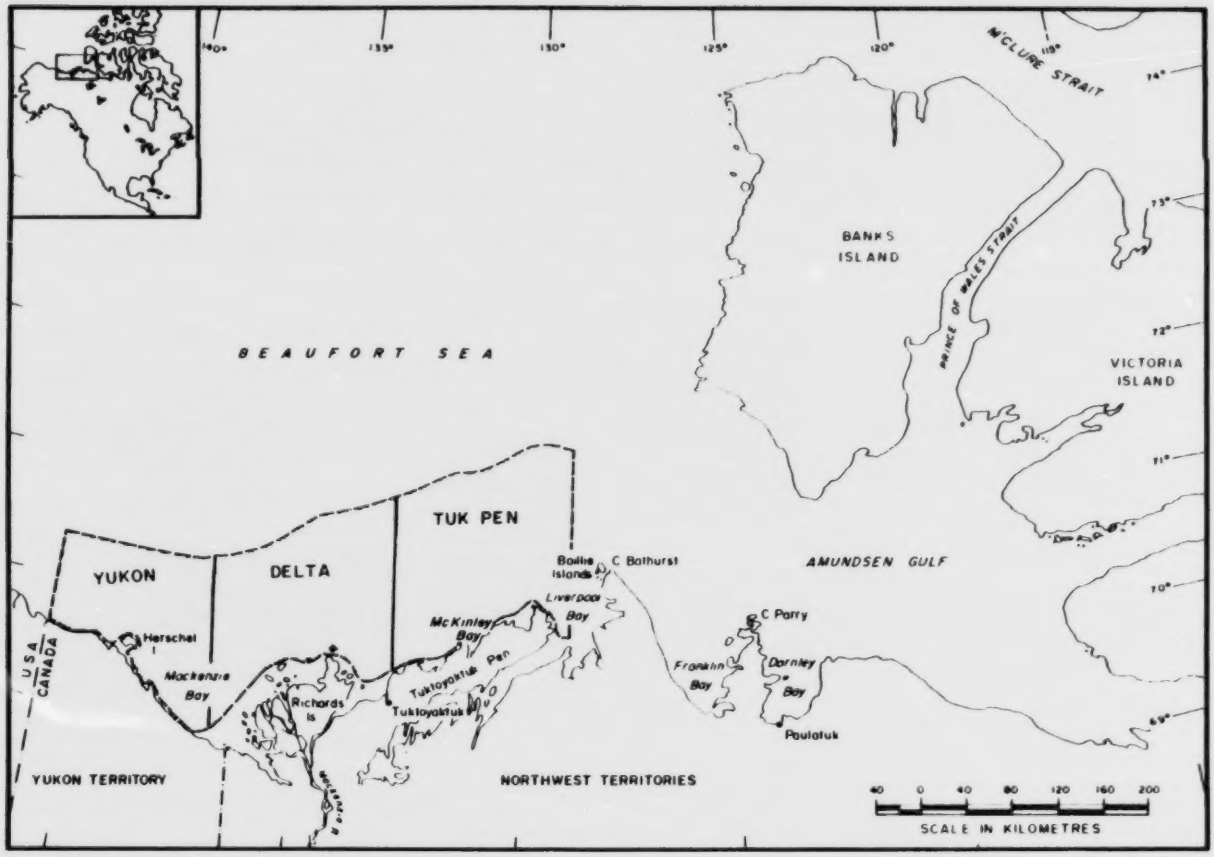


Figure 1. Study area and strata boundaries.

— the distribution of bowheads and annual variability in distributional patterns are determined by physical and biological factors, particularly those influencing large-scale differences in the distribution and abundance of bowhead prey (zooplankton).

The present study contributes information for the eventual evaluation of these hypotheses, but was not specifically designed to test either.

Methods

Aerial Surveys

Six systematic aerial surveys of the southeast Beaufort Sea were flown between 05 July and 18 September 1984. The overall study area extended from the Alaska-Yukon border (141°W longitude) eastward to Cape Bathurst and Franklin Bay (125°47′W longitude), and from the 2 m isobath seaward to a 7-9/10 concentration of pack-ice.

North-south transect lines spaced at intervals of 16 km (July surveys), 20 km (August and September surveys), and 32 km (July surveys) were flown. A strip transect method was used (Caughley 1977; Eberhardt *et al.* 1979), with an effective transect width of 1.6 km (July surveys) and 2.0 km (August and September surveys). Survey coverage ranged from 3–10%, except during late August when 23 additional transect lines were added to increase coverage in areas where bowheads were concentrated (30% Cape Bathurst/Baillie Islands, and 50% each of Yukon coast/Herschel Island and Franklin Bay). The study area was stratified according to boundaries shown on Figure 1; these were established in 1981 surveys and have been used since (Davis *et al.* 1982).

The surveys were conducted from Series 300 de Havilland Twin Otters operated out of Inuvik, NWT. A pilot, co-pilot and two observers were present on all flights. The aircraft were equipped with Global Navigation Systems (GNS 500) or Collins LRN-70 for navigation. The planned survey altitude of 305 m was achieved for 92% of the transect distance surveyed; low overcast conditions necessitated surveying at an altitude of 152 m for the remainder. Surveys were not attempted or were terminated if there was cloud or fog below 152 m, or if sea state exceeded 5 on the Beaufort Scale of Wind Force. Survey speed was 200 km/h, although this varied from approximately 160–220 km/h due to the effects of wind.

During the July surveys, both observers occupied the second rear seat positions behind the cockpit, and searched through a bubble window. During the August and September surveys, the right side observer searched from the co-pilot's seat, in order to take advantage of the enhanced forward visibility. Observations were recorded onto audio tapes, and later

transcribed onto data sheets. Whenever possible, the following information was recorded: species, number of individuals, time and location of sighting, lateral distance of sighting from transect center line, physical habitat associations, species associations, group size, composition and organization, behaviour, and direction and relative rate of movement. Survey conditions, weather, sea state, wave direction, presence and location of any debris accumulations, water colour, and concentration and type of ice were also recorded.

Bowhead densities for each stratum were calculated by dividing the total number of on-transect whales by the strip area surveyed for that stratum. These densities were then used to calculate indices of bowhead abundance, through extrapolation to unsurveyed areas within the strata boundaries. To estimate actual abundance, these indices were corrected for surfaced whales missed by observers, and for whales submerged during the survey pass. Factors used to make these corrections were adopted from previous studies in the region, since the necessary data were not collected in 1984. The following factors were applied:

- 1.43–1.54, to account for 30–35% of surfaced whales missed by observers (after Davis *et al.* 1982), and,
- 4.0–2.5, to account for whales being visible at the surface 25–40% of the time (after Würsig *et al.* 1984).

Satellite imagery

Sea surface temperature and turbidity were chosen as oceanographic indices for this study because (1) they can be measured easily and repetitively over large areas using satellite imagery, and (2) they can be used as indicators of physical circulation, stratification, and heterogeneity. A repetition of observations made more conventionally elsewhere (e.g. Nasu 1966, cited in Gaskin 1976), Borstad (1985) showed that bowhead whales congregate near oceanographic discontinuities such as fronts, eddies, and upwellings that can be seen in satellite imagery. The reason for this probably relates to a local abundance of food organisms at these types of physical phenomena (e.g. Pingree *et al.* 1974; Floodgate *et al.* 1981; Hamner and Hauri 1981).

Digital data from the Advanced Very High Resolution Radiometer (AVHRR) on the American satellite NOAA 7 was obtained from the Atmospheric Environment Service and the University of British Columbia. Sea surface temperature and turbidity patterns in open water and cloud-free areas were determined from analysis of the thermal band (band 4, 10.0–11.3 m in the thermal infrared) and from the visible band (band 1, 0.55–0.90 m), respectively. Processing and calibration of the imagery is described in detail in Borstad (1985).

Results

Distribution—July

Two systematic aerial surveys of the region were conducted during the first half of July. In total, three adult bowheads were seen on-transect. A group of two was sighted 50 km north of King Point, among 1-3/10 ice, while a solitary whale was seen in nearshore, ice-free waters off McKinley Bay.

The third survey in the series was done between 21 and 23 July, and 15 bowheads were seen on-transect. The sightings were made in all strata surveyed, although concentrations were found in only two areas. The first was located 50 km due east of Herschel Island at the edge of the shelf break, and the second in nearshore waters off Cape Bathurst/Baillie Islands. Most whales were seen in clear, marine waters where ice was less than 1/10 concentration. One whale was seen in relatively turbid water off the Tuktoyaktuk Peninsula, and two solitary bowheads were observed lying motionless at the surface among 7-9/10 ice.

The fourth survey was flown from 28 July to 02 August, and seven bowheads were seen on-transect, 100 km off Yukon coast, and 100 km north of McKinley Bay. Most whales were moving during the observation period, although no particular direction was predominant. One solitary bowhead was stationary at the surface among ice concentration of less than 1/10, whereas the others were moving among ice ranging in concentration from 1-3/10.

Distribution—August and September

During the 18–27 August survey, 36 bowheads were seen on-transect. The location of these sightings, along with direction of whale movement, coincident ice conditions, and sites of industry activity are shown on Figure 2. The most notable feature of bowhead distribution during late August was that the whales were congregated in several areas. The behaviour and apparent activities of bowheads therein were different from that of whales observed during the July surveys. A small number of bowheads (six sightings, 18% of total) was seen during the survey outside the coastal congregation areas.

The congregations of bowheads seen in late August were located in Franklin Bay, near Cape Bathurst/Baillie Islands, off Cape Dalhousie at 71°N latitude, and along the Yukon coast between Kay Point and Herschel Island. In addition, two bowheads were seen on-transect at the seaward edge of the Mackenzie River plume, in an area where other researchers estimated 15–25 present on a recent survey (D. Rugh, unpubl. data). Other congregations were seen during the survey, but, because of local whale movements or transect position, were not included in the systematic coverage. These areas were overflown during ferrying flights, however, and congregations of bowheads were seen nearshore at Komakuk Beach, along the north and northwest coasts of Herschel Island, and along the Yukon coast between King and Shingle points. Several bowheads seen near Komakuk and between King and Shingle were within 100 m of the beach.

The extent of usage of the congregation areas varies among days and areas. Bowheads were sighted in some locations, such as along the coasts of Herschel Island, each time the area was overflown (twice in August and four times in September). At other locations such as near Komakuk, bowheads were observed on some days (e.g. 18 August) but not others (e.g. 27 August).

The activities of bowheads recorded in the coastal congregation areas were generally similar to feeding and socializing behaviours described by Ljungblad *et al.* (1984) for bowheads in Alaskan waters. Behaviour patterns that were observed during the late August survey included: milling (whales swimming slowly around each other at the water

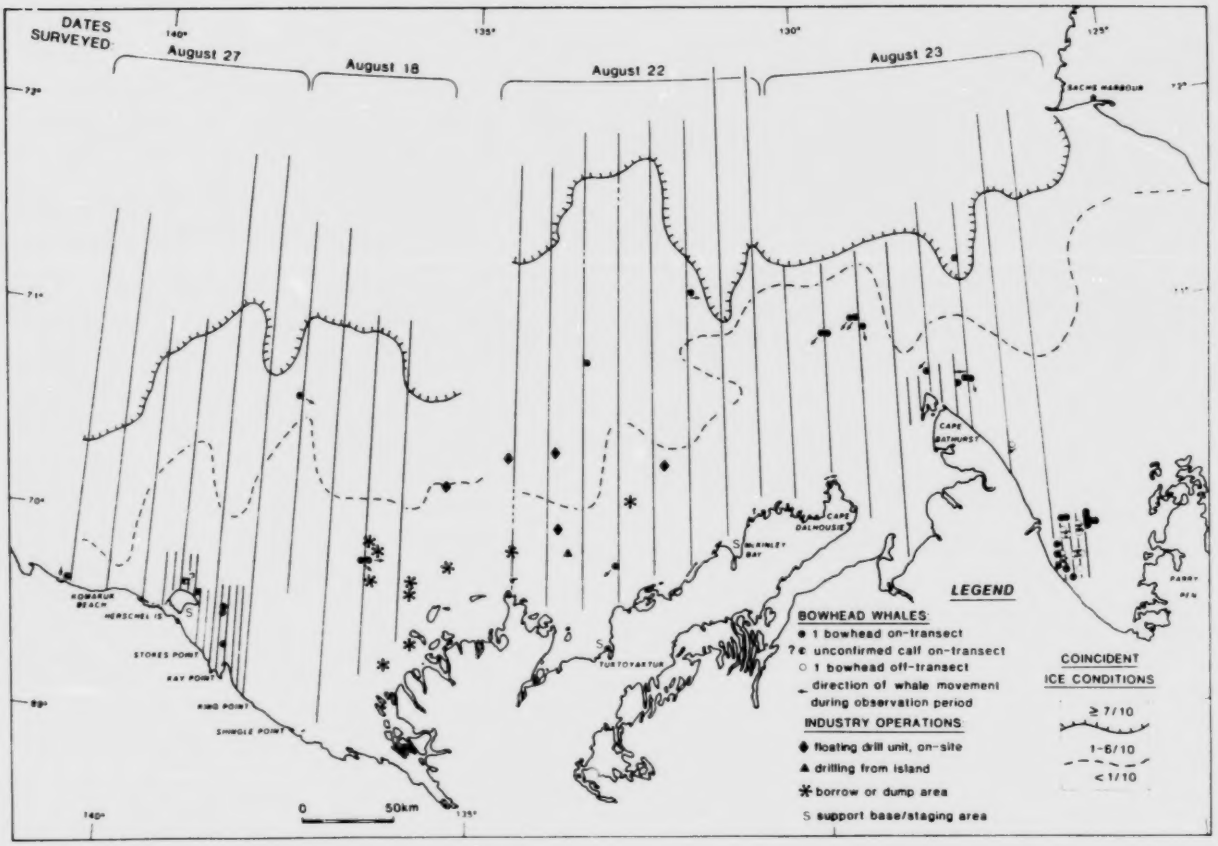


Figure 2. Bowhead whale sightings- systematic survey, 18–27 August 1984.

surface); physical interaction of cow-calf pair; displaying (rolling, flipper slapping); possible bottom feeding (mud streaming from mouth); swimming slowly along edge of surface discontinuity or front; and surface feeding (open-mouth surface swimming).

Whales observed outside the congregation areas were seen as solitary and were within ice concentrations ranging from 1-7/10. These whales were all either swimming at the surface, diving, or lying still at the surface. Because not all whales within a group may surface during the survey pass, the above sightings may have included only part of a group. Therefore, it cannot be concluded that individuals noted as solitary were necessarily alone and in a 'non-congregation' area.

The final survey in the series was flown 06–18 September, and 42 bowheads were seen on-transect (Fig. 3). As in late August, the whales were sighted primarily in nearshore congregation areas, located just off the Yukon coast between King and Shingle points, northeast of Kay Point at 69°30′N latitude, at the seaward edge of the Mackenzie plume, along the coasts of Herschel Island, in Franklin Bay, and north of Cape Dalhousie at 71°N latitude. The activities of bowheads observed in the congregation areas in September were similar to those seen in August, although one additional display behaviour (breaching) was noted.

Abundance

Bowhead densities for each stratum, by survey, are shown in Figure 4. In the Yukon stratum, densities peaked twice during the open water period, initially during late July and then again in September. In the Delta and Tuktoyaktuk Peninsula strata, densities peaked in late July and then declined through August and September. These data probably reflect arrival of the population in the southeast Beaufort during late July, and then a gradual movement to and through the Yukon stratum as summer progressed.

The study was not designed or intended to derive empirical estimates of bowhead abundance, but rather to provide a general indication of distributional patterns as they relate to industry and oceanography. It was beyond the scope of the study to collect data necessary to calculate correction factors specific to 1984 observers, whale surfacing behaviour, and survey conditions. However, correction factors calculated during previous years have been applied to the 1984 data, to provide a general indication of actual bowhead abundance in the region. When interpreted in the broad sense intended, the abundance estimates are probably reasonable given that the factors used were broadly and conservatively set (Table 1). The data suggest that in early July, from 100–300 bowheads were present in the region. The total number present increased thereafter, and peaked in September when an estimated 1500–2400 were present.

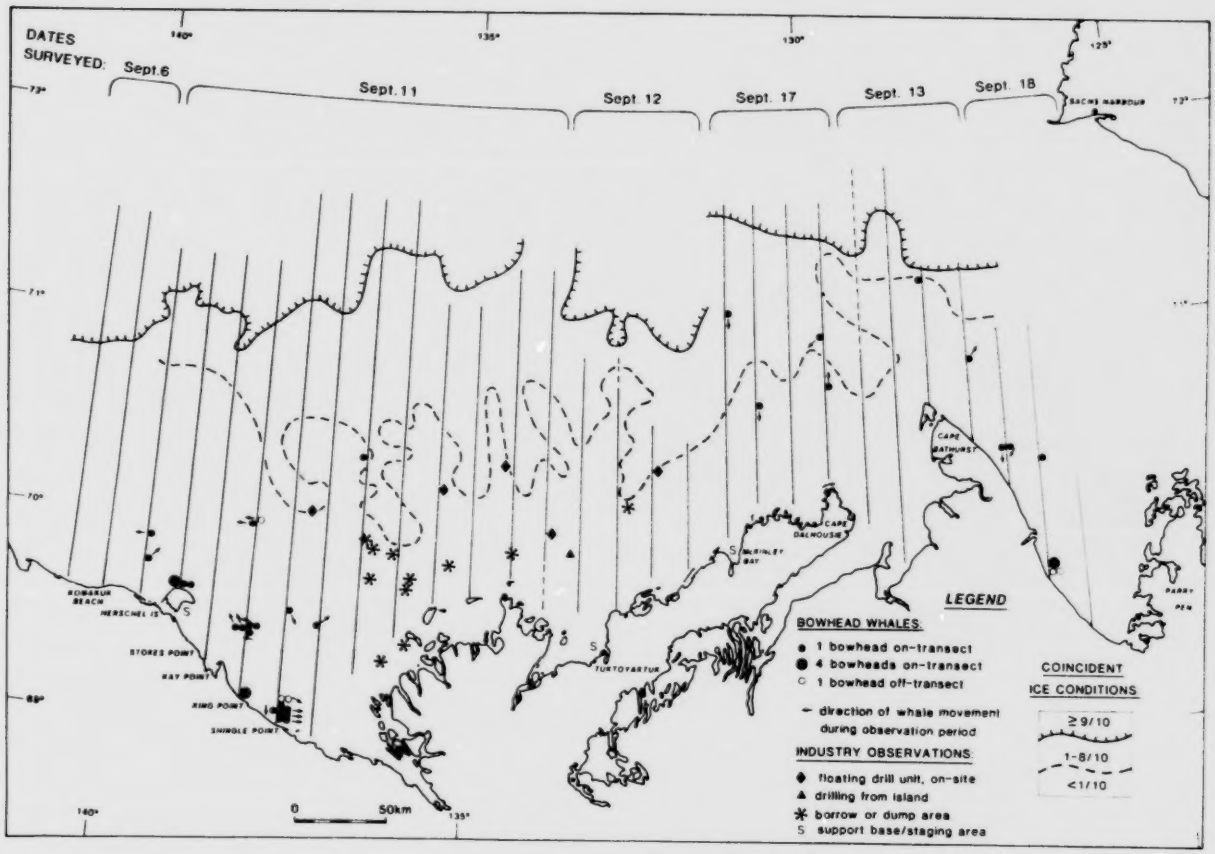


Figure 3. Bowhead whale sightings- systematic survey, 06-18 September 1984.

TABLE 1
Corrected estimates of bowhead abundance in the southeast Beaufort Sea, July-September 1984*

	Strata				
Survey	Yukon	Delta	Tuk Pen	West Amundsen	Total
05-09 July	-	-	0-100	NS	100
13-18 July	200-300	-	-	NS	200-300
21-23 July	500-900	300-500	100	NS	900-1500
28 July-02 Aug.	400-800	100-200	300-500	NS	800-1500
18-27 Aug.	100-200	100-200	300-400	300-500	800-1200
06-18 Sept.	1000-1600	100	100-200	300-500	1500-2400

* estimates rounded to nearest 100 (range reflects range of correction factors used)

Satellite oceanography

In 1984, bowheads were congregated near Cape Bathurst and in Franklin Bay, where satellite imagery showed vigorous convergent surface circulation. Airborne observations showed that half (9 of 18) of the animals sighted on 23 August were located near visible discontinuities, or ice strings that mark temporary surface convergences. It may also be important to note that Franklin Bay is located where the end of a submarine canyon rises abruptly to the coast. Subsurface flow in such a region could also be expected to be complex, and local upwelling is a possibility.

Large congregations of bowheads were also found along the western edge of the river plume, and off the Yukon coast, when wind-driven water movements favoured upwelling, prograde fronts in that region. Most were on the colder, clearer side of the sharpest thermal and turbidity gradients. Large numbers of bowheads were present at this type of front in 1983 (Borstad 1985). In general, the complicated bottom topography (steeply sloping bottom close to the coast, and the presence of Herschel Canyon and of islands and promontories) probably magnifies the heterogeneity of this region.

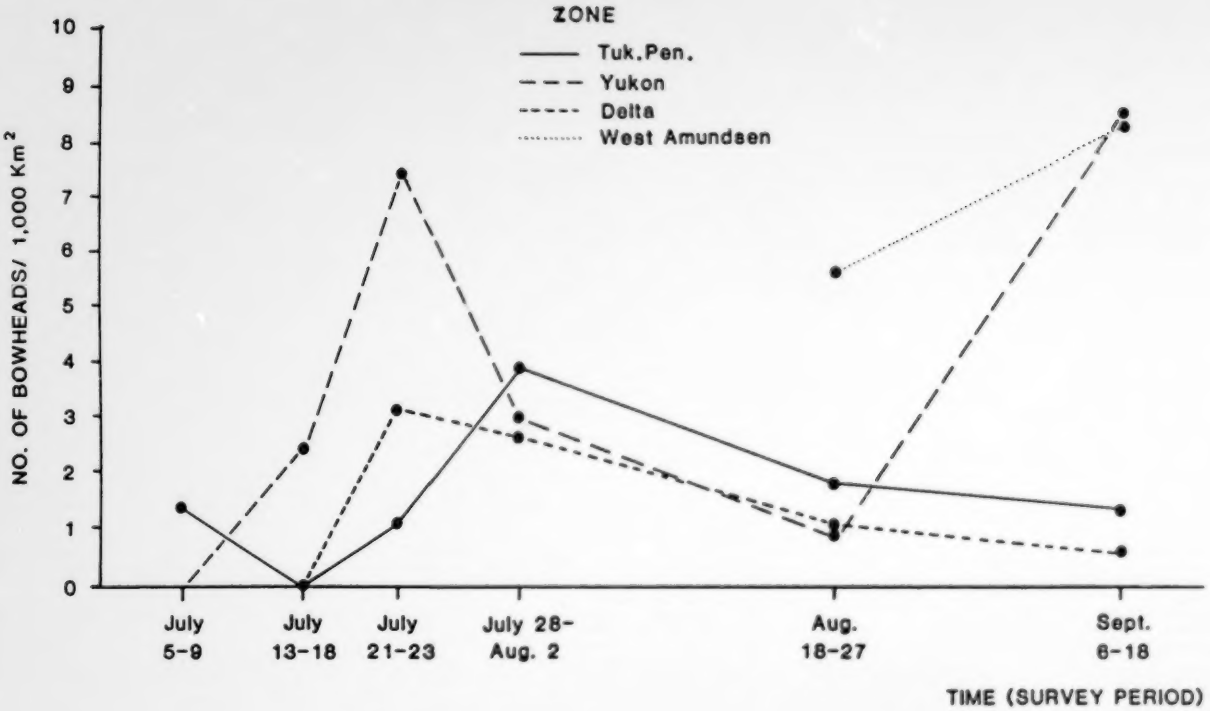


Figure 4. Observed bowhead densities in the southeast Beaufort Sea, July-September 1984.

The third congregation area, located north of the Tuktoyaktuk Peninsula at 71°N latitude, has been used by large numbers of bowheads and ringed seals during past surveys. In 1984, no satellite imagery was available for this area.

Discussion

The southeast Beaufort Sea has been used by substantial numbers of bowhead whales during late August and/or September in all years in which surveys have been conducted. The total number of bowheads estimated for the region has been relatively consistent among years (e.g. within the range from 1500–2000). It is probable that a portion of the population summers in Amundsen Gulf, in Alaskan waters, or both. It is also possible that the method used repeatedly underestimated the number of whales present, since the population is believed to contain approximately 4000 animals (IWC 1984).

Although the overall abundance of bowheads in the region appears to have been relatively consistent during 1981–84 surveys, the specific locations where bowheads have congregated have varied markedly. For example, in 1980, bowheads were concentrated off the Tuktoyaktuk Peninsula (Renaud and Davis 1981). This area was also used in 1981, but to a lesser extent than in 1980, and the specific locations where whales congregated were different. Yukon coastal waters were used by large numbers of bowheads in August 1983 and September 1984, but to a limited extent in 1981, 1982, and September 1983.

Following the reasoning that bowheads must feed on local concentrations of zooplankton, and that zooplankton are often, but not always, found in greater abundance at physical discontinuities, a map of geographic areas often showing physical features that appear to have some importance to bowheads has been prepared (Fig. 5). This highly generalized and simplified picture is an attempt to represent areas of higher probable abundance of zooplankton and will be modified by physical and biological events in any one year. Because zooplankton growth and reproduction in the Arctic is closely synchronized with phytoplankton blooms, several factors will presumably be important on regional or local scales including: timing and geographic extent of ice break-up and pack movements, overall cloud cover affecting available light during the open water months, and vertical movements of water that can alleviate nutrient depletion for phytoplankton in certain regions.

Factors determining the character of oceanographic fronts operate on a variety of time and space scales, but the small-scale features that last for a few hours or days are probably less important to bowheads than larger and more long lasting events. If food abundance were the major factor influencing bowhead movements (probably an oversimplification), the largest bowhead congregations would be expected in regions that have the largest, most sustained zooplankton supply, whereas other geographic regions would support only small numbers of scattered individuals. Over the long term, the Herschel Island, Yukon coast and Cape Bathurst/Franklin

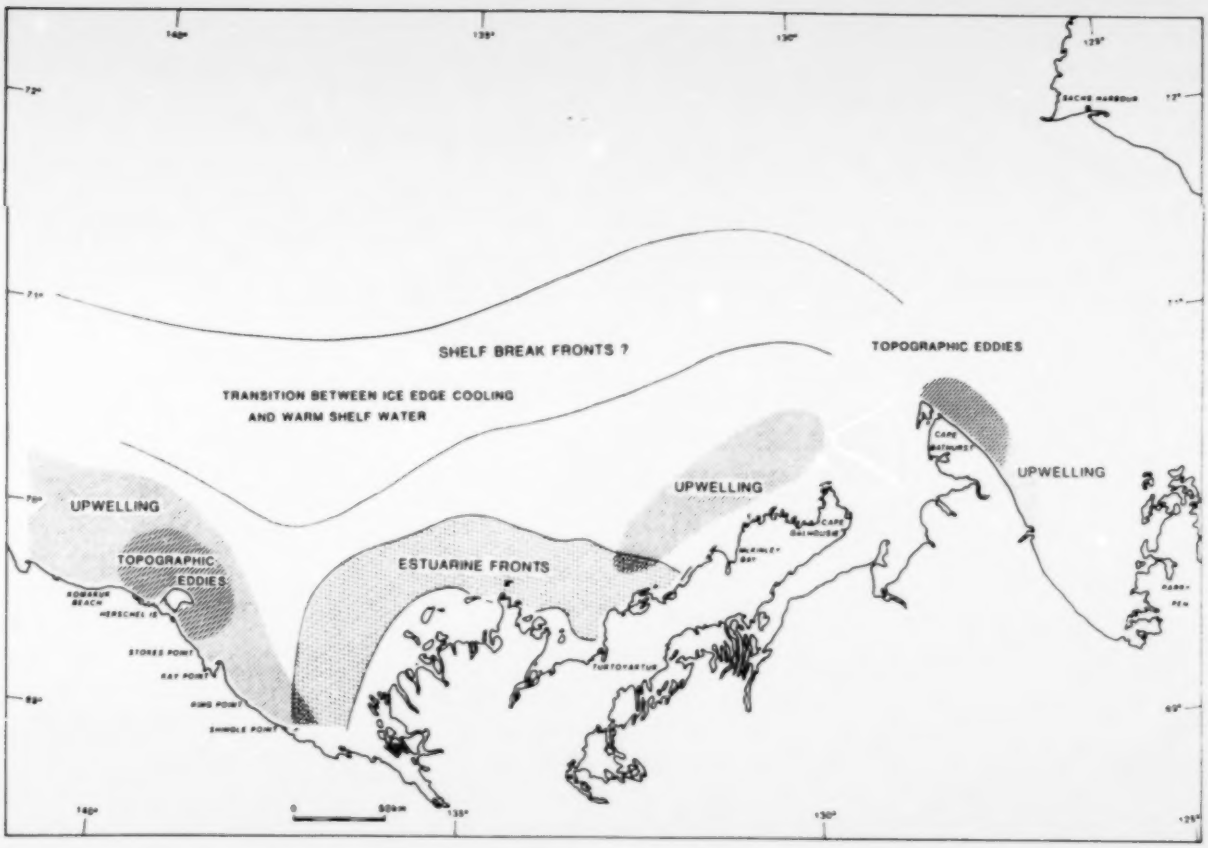


Figure 5. Distribution of major oceanographic features in the southeast Beaufort Sea during late summer.

Bay areas seem to be important, both in terms of the types of surface oceanographic features there, and the documented abundance of bowheads. The large area over the Tuktoyaktuk Peninsula shelf and along the Mackenzie River plume, which includes the industry zone, appears to have a more variable attractiveness to bowheads.

The results of the present study and that of Borstad (1985) suggest that physical and biological oceanographic factors probably have a significant influence on bowhead distribution in this region. This conclusion is based on the 1983 and 1984 findings that bowheads tend to congregate near oceanographic features that often attract or concentrate zooplankton in other regions. Although this study lends support to the hypothesis that the observed variability in bowhead distribution is related to food availability, it cannot invalidate the alternate hypothesis that industrial activities may be excluding whales from certain areas. To confirm the link between whale distribution and oceanographic features identifiable in satellite imagery, *in situ* sampling of the relative density of zooplankton at fronts where whales feed would be required.

Acknowledgments

The August and September surveys were funded by the Environmental Studies Revolving Funds and by Indian and Northern Affairs Canada. The work was done under contract to ESL Environmental Sciences Ltd., Sidney, B.C. The July surveys were funded by Canada, Dept. of Fisheries and Oceans, and were done under contract to PN Research Projects, Sidney, B.C. The Scientific Advisors for the studies were Dr. John Ward, Mr. Ricki Hurst, and Mr. Michael Kingsley.

Observers for the surveys were: L. Harwood, P. Norton, R. Hurst, J. McDonald, J. Ford, and J. Darling. The aircraft were chartered from Kenn Borek Air Ltd., Inuvik, NWT. Employees of the Atmospheric Environment Service in Tuktoyaktuk and Inuvik, NWT provided daily weather briefings and forecasts. Dr. Michael Lawrence allowed use of imagery and oceanographic data from July 1984 for inclusion in this study. Andrew Thomas was responsible for reception of imagery at the University of B.C., and J.F.R. Gower allowed use of the image processing laboratory at the Institute of Ocean Sciences, Sidney, B.C. Brian Sawyer drafted the figures.

References

Borstad, G.A. 1985. Water colour and temperature in the southern Beaufort Sea: remote sensing in support of ecological studies of the bowhead whale. Canadian Technical Report on Fisheries and Aquatic Sciences 1350. 69p.

Caughley, G. 1977. Sampling in aerial survey. Journal of Wildlife Management 41(4):605-615.

Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans, and W.G. Alliston. 1982. Distribution, numbers and productivity of the western Arctic stock of bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Prep. by LGL Ltd., Toronto, for Dome Petroleum, and Sohio Alaska Petroleum. 135p.

Eberhardt, L.L., D.G. Chapman, and J.R. Gilbert. 1979. A review of marine mammal census methods. Wildlife Monograph No. 63. 46p.

FEARO (Federal Environmental Assessment Review Office). 1984. Beaufort Sea hydrocarbon production and transportation. Report of the Environmental Assessment Panel, No. 25. 146p.

Floodgate, G.D., G.E. Fogg, D.A. Jones, K. Lochte and C.M. Turley. 1981. Microbiological and zooplankton activity at a front in Liverpool Bay. Nature 290:133–136.

Gaskin, D.E. 1976. The evolution, zoogeography and ecology of Cetacea. Oceanography and Marine Biology: An Annual Report 14:247–346.

Hamner, W.M. and I.R. Hauri. 1981. Effects of island mass: water flow and plankton pattern around a reef in the Great Barrier Reef Lagoon, Australia. Limnology and Oceanography 26:1084–1102.

Harwood, L.A. and J.K.B. Ford. 1983. Systematic aerial surveys of bowhead whales and other marine mammals in the southeastern Beaufort Sea, August–September 1982. Prep. by ESL Environmental Sciences Ltd., for Dome Petroleum and Gulf Canada Resources. 70p.

IWC (International Whaling Commission). 1984. Report of the subcommittee on other protected species and aboriginal/subsistence whaling. International Whaling Commission Report 34:131.

LGL Environmental Research Associates, ESL Environmental Sciences Ltd., and ESSA Environmental and Social Systems Analysts Ltd. 1984. Beaufort Environmental Monitoring Project, 1983–84 report. Prep. for Dept. of Indian and Northern Affairs and Environment Canada. 292p.

Ljungblad, D.K., S.E. Moore, and D.R. Van Schoik. 1984. Aerial surveys of endangered whales in the northern Bering, eastern Chukchi, and Alaskan Beaufort Seas, 1983: with a five year review, 1979–1983. Technical Report 955. Prep. by Naval Ocean Systems Center, San Diego, for Minerals Management Service, Alaska. 119p.

McLaren, P.L. and R.A. Davis. 1985. Distribution of bowhead whales and other marine mammals in the southeast Beaufort Sea, August–September 1983. Environmental Studies Revolving Funds Report, No. 001, Ottawa. 62p.

Pingree, R.D., G.R. Forster, and G.K. Morrison. 1974. Turbulent convergent tidal fronts. Journal of the Marine Biological Association of the United Kingdom 54:469–479.

Renaud, W.E. and R.A. Davis. 1981. Aerial surveys of bowhead whales and other marine mammals off the Tuktoyaktuk Peninsula, NWT, August–September 1980. Prep. by LGL Ltd., for Dome Petroleum. 55p.

Würsig, B., E.M. Dorsey, M.A. Fraker, R.S. Payne, W.J. Richardson, and R.S. Wells. 1984. Behaviour of bowhead whales *Balaena mysticetus*, summering in the Beaufort Sea: surfacing, respiration, and dive characteristics. Canadian Journal of Zoology 62:1910–1921.

THE BRYOGEOGRAPHICAL SIGNIFICANCE OF THE TORNGAT MOUNTAINS, NORTHERN LABRADOR

Terry A. Hedderson

Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X9

Level: Master's

Abstract

While the bryophyte flora of the Torngat Mountains of northernmost Labrador is composed primarily of circumpolar arctic or boreal species with wide distributions, many moss and liverwort species have distributional limits there. Species of high arctic affinity, e.g. *Oligotrichum falcatum*, have their southern limits in the Torngat, while several boreal or temperate species, e.g. *Hylocomium pyrenaicum*, occur there at their northern limit. There is also a large disjunct bryophyte element in the Torngat Mountains, comprising mainly montane species with a broad range in western North America but occurring in only a few localities in eastern North America, e.g., *Andreaea nivalis*, *Hydrogrimmia mollis*, *Marsupella revoluta*. Previously undescribed species of mosses have recently been discovered at Nachvak Fiord; these apparent endemics are known only from the highest parts of the Torngat. The disjunct and endemic bryophyte elements at Nachvak and elsewhere in the Torngat Mountains provide strong botanical evidence to support the theory that several high plateaus there remained ice-free during the Wisconsin Glaciation. Thus the area could have been an important refugium for plant and animal species, and the Nachvak Fiord region may be particularly critical in this respect.

Key words: Labrador, Torngat Mountains, phytogeography, bryophytes.

Résumé

Bien que la flore de bryophytes des monts Torngat, à l'extrême nord du Labrador, se compose surtout d'espèces circumpolaires, arctiques, ou de taïga à vaste répartition, de nombreuses mousses et hépatiques atteignent là leur limite de végétation. Les espèces de l'Extrême-Arctique (p. ex. *Oligotrichum falcatum*) ont leur limite méridionale dans les monts Torngat, alors que plusieurs espèces de la taïga ou des régions tempérées (p. ex. *Hylocomium pyrenaicum*) y établissent leur limite septentrionale. Il y existe également un large groupe de bryophytes appartenant surtout aux espèces montagnardes largement répandues dans l'Ouest de l'Amérique du Nord, mais présentes seulement dans quelques endroits de l'Est (par ex. *Andreaea nivalis*, *Hydrogrimmia mollis* et *Marsupella revoluta*). Récemment, des espèces non encore décrites de mousses ont été découvertes dans le fiord Nachvak; ces plantes apparemment endémiques ne se retrouvent que sur les hauteurs les plus élevées des monts Torngat. Les bryophytes endémiques et à habitat discontinu du fiord Nachvak et de certains endroits des monts Torngat fournissent une preuve botanique solide de la non-occupation par les glaciers de plusieurs hauts-plateaux au cours de la glaciation de Wisconsin. Ces régions ont pu servir à ce moment-là de refuge aux espèces végétales et animales; la région du fiord Nachvak est d'importance cruciale en cette manière.

Mots-clés: Labrador, monts Torngat, géographie botanique, bryophytes.

Introduction

The Torngat Mountains (located near the tip of the Quebec-Labrador Peninsula, Figure 1) are, for three reasons, of outstanding importance to bryogeography in eastern North America:

1) The Torngat, though lying wholly within the arctic tundra region of northern Quebec-Labrador (Payette, 1983), are relatively close to the northernmost extension of the Boreal biome into the region. Thus, bryophyte species of boreal affinity may be expected to reach

northern limits in the Torngat since a) the mountains may present a physical barrier to northward movement of species or, b) varied climate, typically associated with varied topography in mountainous regions (Banfield, 1981), may provide suitable conditions for the establishment of species with the bulk of their range further south. The latter appears to be so with balsam poplar, which occurs in sheltered valleys at Saglek Fiord (Payette, 1983) and Ramah Bay (Rousseau, 1974), more than 100 km north of its main range in Labrador.

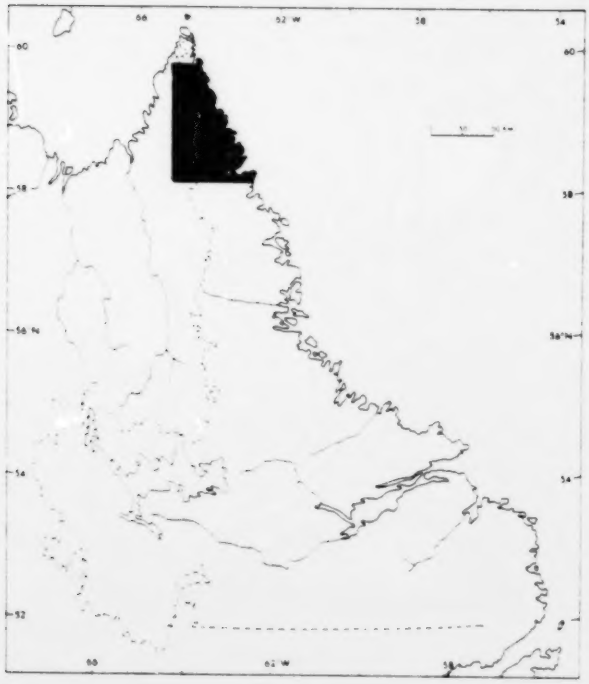


Figure 1. Map of Labrador indicating the position of the Torngat (shaded).

2) The numerous plateaux occurring at high elevations throughout the Torngat, present an aspect similar to that of the arctic deserts, found far north of the region. These may permit southward extensions of range for species of high-arctic affinity and the Torngat may be expected to represent a southern limit for some of these.

3) Recent geomorphological evidence (Evans & Rogerson, 1986; Ives, 1974, 1978) suggests that at least some parts of the Torngat remained ice free for the duration of the last glacial epoch. Some of the land surfaces in the region are therefore ancient, and this presents two intriguing possibilities: a) bryophytes may have survived the vicissitudes of Pleistocene (and perhaps earlier) glaciations in northern Labrador, so that a significant element consisting of pre-glacial relicts may be present in the bryoflora. If refugia did exist, then they may have been the source from which at least part of the flora of adjacent, glaciated areas was derived upon melting of the ice sheet; b) if land surfaces have been continually available, at least part of the flora may have been isolated for sufficient time to allow speciation, and the development of a small endemic element.

In spite of their potential importance, the Torngat have, until recently, remained a bryological *terra incognita*. Virtually no bryophytes were collected from the region before 1975, when a few coastal localities were visited by D.P. Weber. Several phytogeographically critical species were subsequently reported from the region based on these collections (Brassard & Weber, 1978). No other collections were made in the Torngat until 1983, when I visited 12 localities on the South side of Nachvak Fiord, resulting in the addition of several critical, and numerous phytogeographically interesting, species to the bryoflora of the territory (Hedderson & Brassard, 1986). A second field season was completed in 1986, during which collections were made at localities on the North side of Nachvak Fiord, and in the Delabarre Bay area. Material examined to date from these collections include various critical bryophytes, but most of the specimens from 1986 remained unidentified.

The Torngat thus constitute a critical region for our understanding of bryogeographical patterns in the flora of eastern North America. In this paper I will evaluate as far as possible the bryogeographical significance of the Torngat, with respect to the flora of eastern North America, by analysis of continental distributions of all bryophyte species.

Methods

All data sources cited above were used to compile a list of bryophyte species for the Torngat Mountains. Nomenclature generally follows Crum, Steere & Anderson (1973) for mosses and Stotler & Crandall-Stotler (1977) for hepatics. Major sources of information were regional floras (Crum & Anderson, 1981; Ireland, 1982; Lawton, 1971; Schuster, 1966–80), taxonomic revisions (Bremer, 1980a,b; 1981; Horton, 1982, 1983; Ireland, 1969; Lewinsky, 1974; Shaw, 1982; Vitt, 1970), and numerous previously published distribution maps (listed in Sjödin, 1980a,b).

Floristic analysis

The Torngat moss flora falls into seven major North American distributional groups (Table 1) based in part on Schofield (1972, 1980), Schofield and Crum (1972), and Steere (1965, 1978). These are further subdivided on the basis of continuity and extent of continental distribution. Of the 218 bryophyte species (201 mosses and 17 hepatics) occurring in the Torngat, 31 (14%) are ubiquitous in North America, and an additional 66 (30%) are widespread in arctic and boreal regions of the continent. The remainder of the flora is comprised of species showing more restricted distributions in North America, and each of the five major categories into which these fall is discussed separately below.

The Boreal Element. Nineteen species, comprising 10% of the total bryophyte flora of the Torngat, are, in North America, predominantly restricted to boreal regions. Seven of these are ± transcontinental:

Brachythecium erythrorrhizon
Climacium dendroides
Hylocomium pyrenaicum
Orthodicranum flagellare

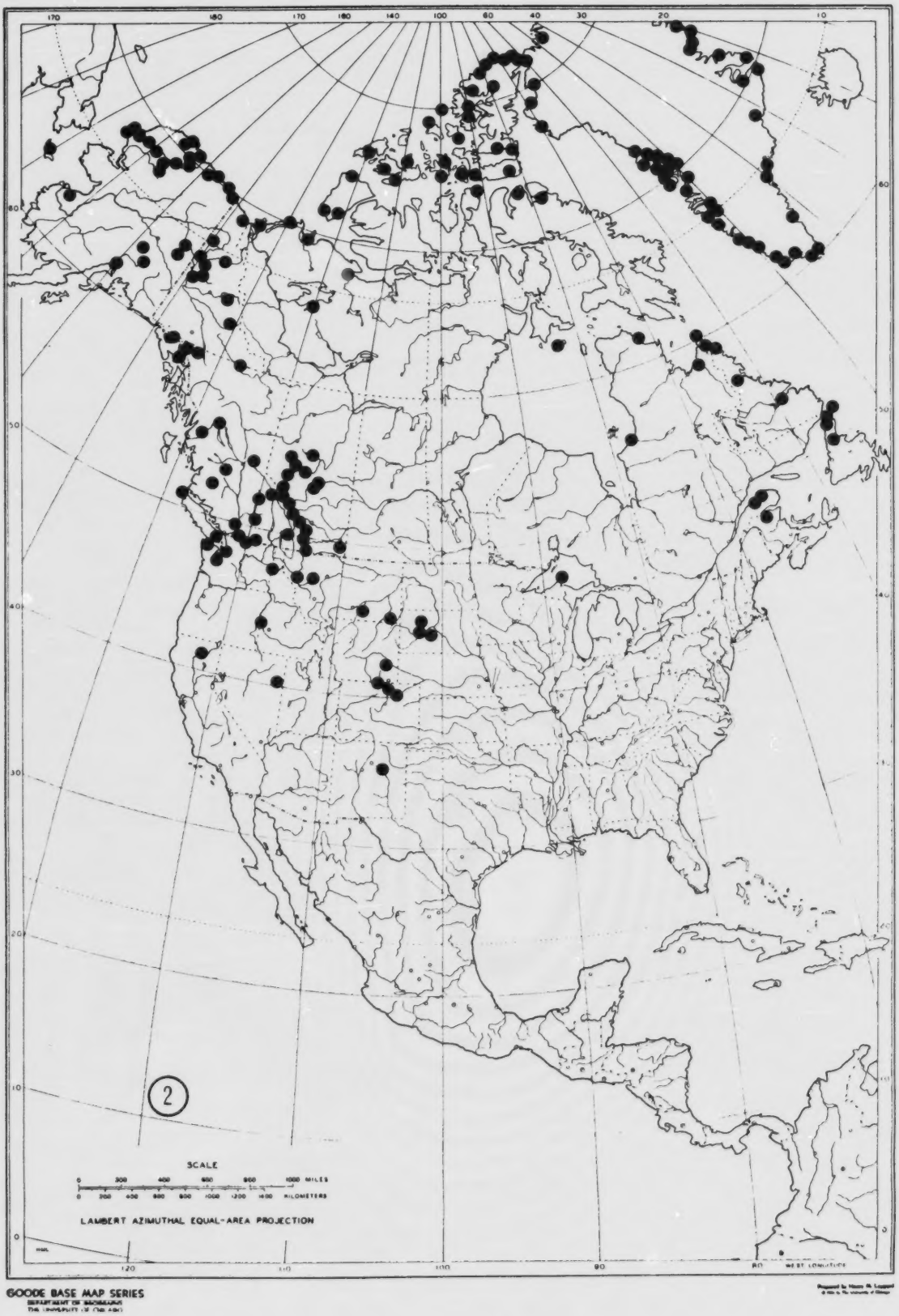


Figure 2. The North American distribution of *Timmia austriaca* (adapted from Brassard, 1980).

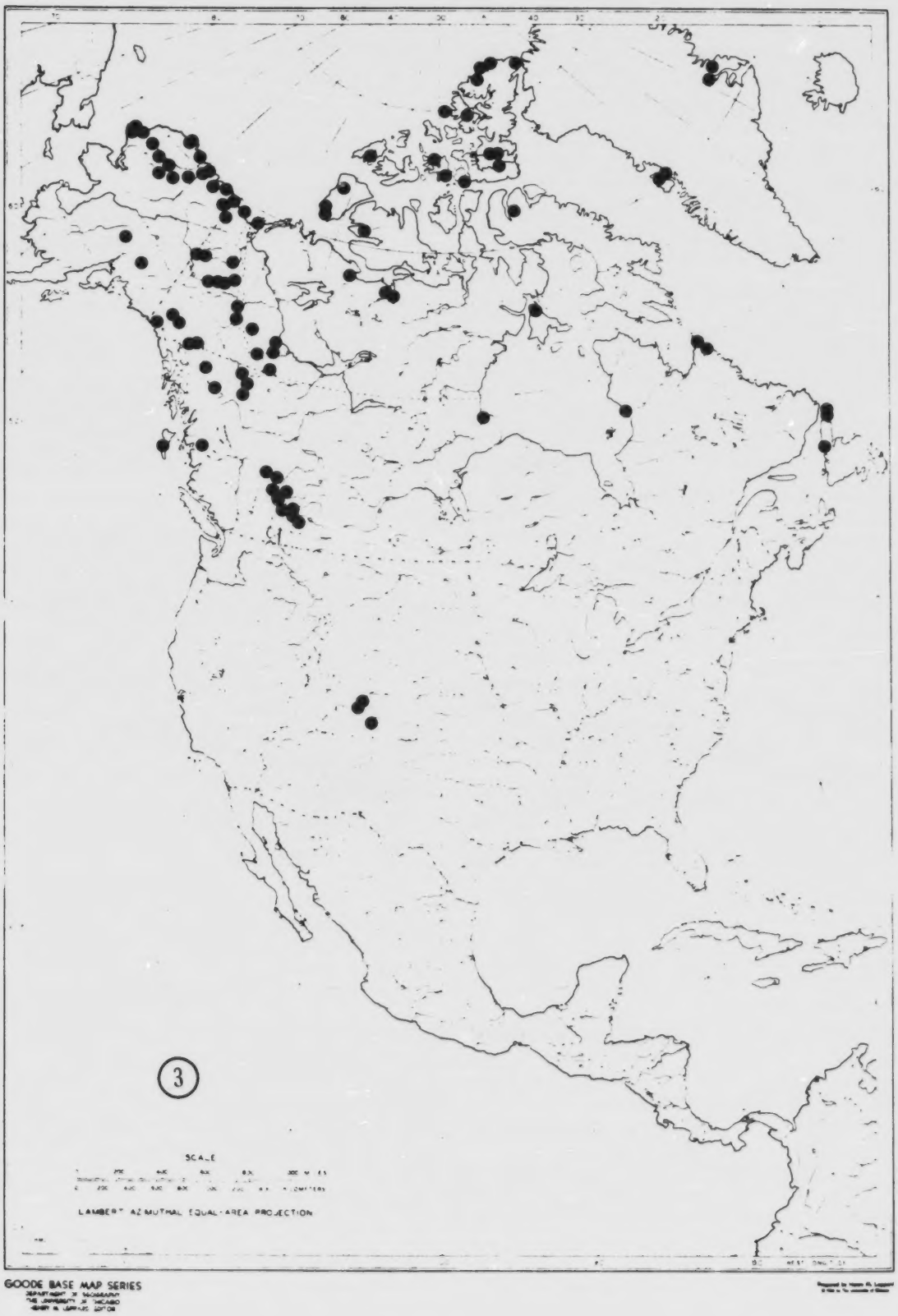


Figure 3. The North American distribution of *Encalypta alpina* (expanded and adapted from Horton, 1983).

TABLE 1
The North American distributions of the Torngat moss flora. Percentages are for major distributional categories only.

Distributional Category	# in sub-category	# in major category	% of total flora
I Ubiquitous		31	14
II Arctic-Boreal		66	30
III Boreal			
1) Transcontinental	7		
2) Disjunct	11	19	9
3) Eastern North America	1		
IV Arctic-Montane			
1) Transcontinental	28	41	19
2) Disjunct	13		
V Arctic			
1) Transcontinental	25	26	13
2) Disjunct	1		
VI Montane			
1) Disjunct	27		
2) Eastern North America	4	34	15
3) Endemic to Torngat	4		
Total		218	100

Paraleucobryum longifolium
Pohlia wahlenbergii
Pseudobryum cinclidioides

Of the remaining 12 species, 11 are disjunct between eastern and western North America:

Calliergon wickesii
Hygrohypnum ochraceum
Plagiothecium laetum
Plagiothecium denticulatum
Pohlia lescuriana
Racomitrium fasciculare
Racomitrium heterostichum
Racomitrium microcarpon
Sphagnum quinquefarium
Sphagnum platyphyllum
Sphagnum russowii

A single boreal species, *Ditrichum lineare*, is restricted to eastern North America. All except two of the boreal species (*Racomitrium fasciculare*, *R. heterostichum*) reach their northern limit of eastern North American distribution in the Torngat.

The Arctic-Montane Element. This element includes species which occur in arctic regions of the continent, and extend their range southward in mountains. Forty species (18% of the total) with this type of distribution are known from the Torngat. Most (28) of the arctic-montane species are essentially transcontinental at arctic latitudes and of these, only two, *Andreaea obovata* and *Drepanocladus tundrae*, are at their southern limit. Of the remaining transcontinental arctic-montane species, the majority are essentially continuous in distribution between the Torngat and their populations further south:

Bartramia ithyphylla
Calliergon sarmentosum
Conostomum tetragonum
Dicranoweisia crispula
Dicranum acutifolium
Dicranum angustum
Dicranum elongatum
Dicranum groenlandicum
Encalypta brevicolla
Gymnomitrion concinnatum
Orthotrichum pylaisii
Plagiobryum zierii
Racomitrium lanuginosum
Rhytidium rugosum
Saelania glaucescens
Tetralophozia setiformis
Timmia austriaca (Figure 2)

Nine of the species, however, are disjunct in eastern North America between their arctic (including Torngat) populations and montane stations in the Gulf of St. Lawrence region (Belland, 1984):

Cyrtomnium hymenophylloides
Encalypta alpina (Figure 3)
Myurella tenerrima
Odontoschisma macounii
Orthothecium chryseum
Orthothecium strictum
Pohlia filum
Timmia norvegica
Tortella arctica

Thirteen of the arctic-montane species are disjunct between eastern and western North America:

Andreaea blyttii
Arctoa fulvella
Arctoa hyperborea
Bryum pallens
Grimmia donniana
Grimmia torquata
Kiaeria blyttii
Kiaeria starkei
Pleurocladula albescens
Pohlia drummondii (Figure 4)
Pohlia obtusifolia
Polytrichastrum sexangulare
Tayloria lingulata

Only one of these, *Arctoa hyperborea*, reaches a southern limit in the Torngat. Of the twelve that occur further south, four (*Arctoa fulvella*, *Grimmia donniana*, *Kiaeria starkei*, *Polytrichastrum sexangulare*) are disjunct in eastern North America from the Torngat to the Gulf of St. Lawrence region (where all but *P. sexangulare* occur as far south as the mountains of New England). The remainder are more or less continuous between their arctic and southernmost montane stations.

The Arctic Element. Twenty six (13%) of the species occurring in the Torngat have their main center of continental distribution in arctic regions and do not extend southward in mountainous areas. All but one of these (*Bryum purpurascens*) are transcontinental at arctic latitudes and the apparent disjunction in this species' distribution is likely

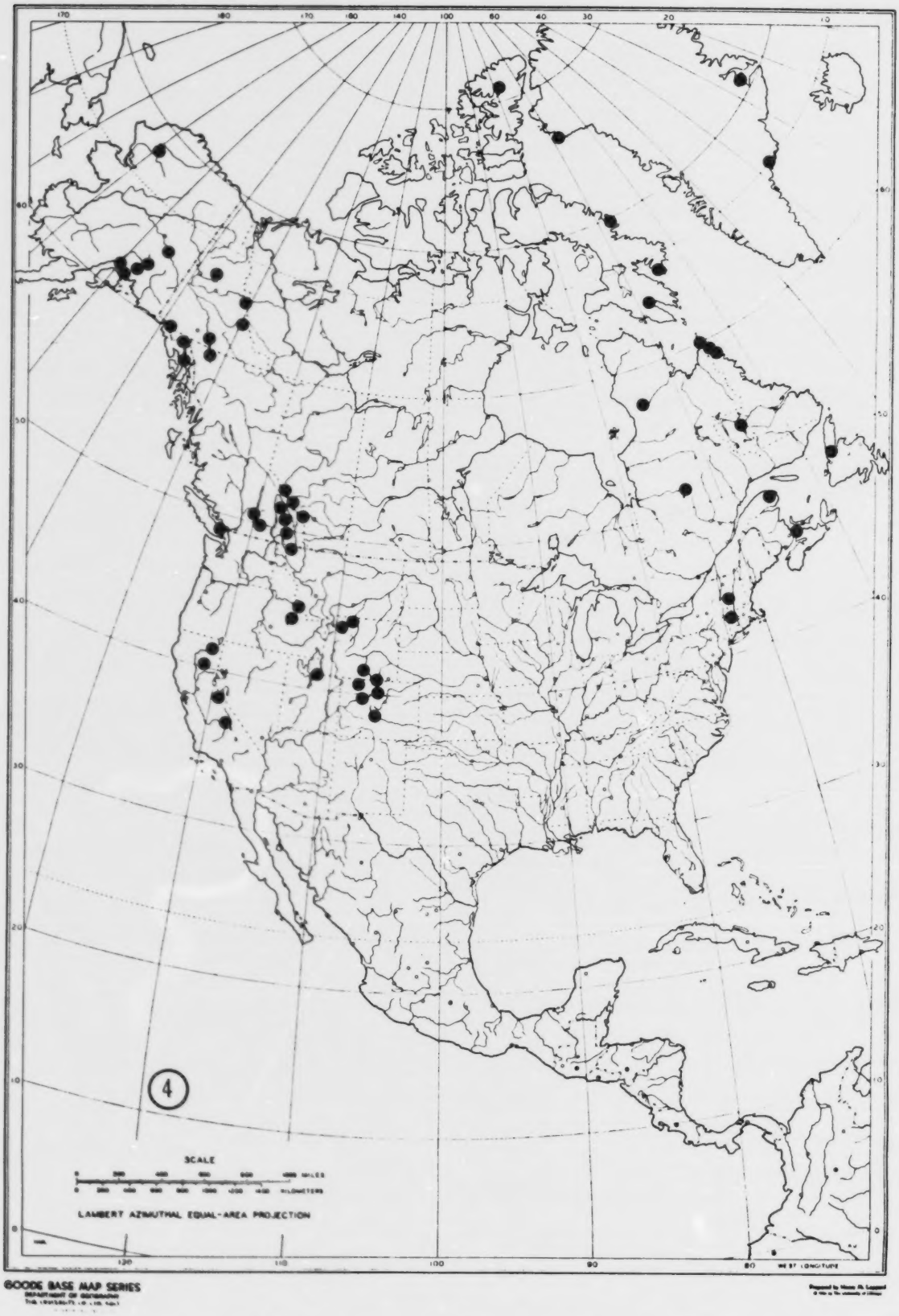


Figure 4. The North American distribution of *Pohlia drummondii* (expanded from Shaw, 1982).

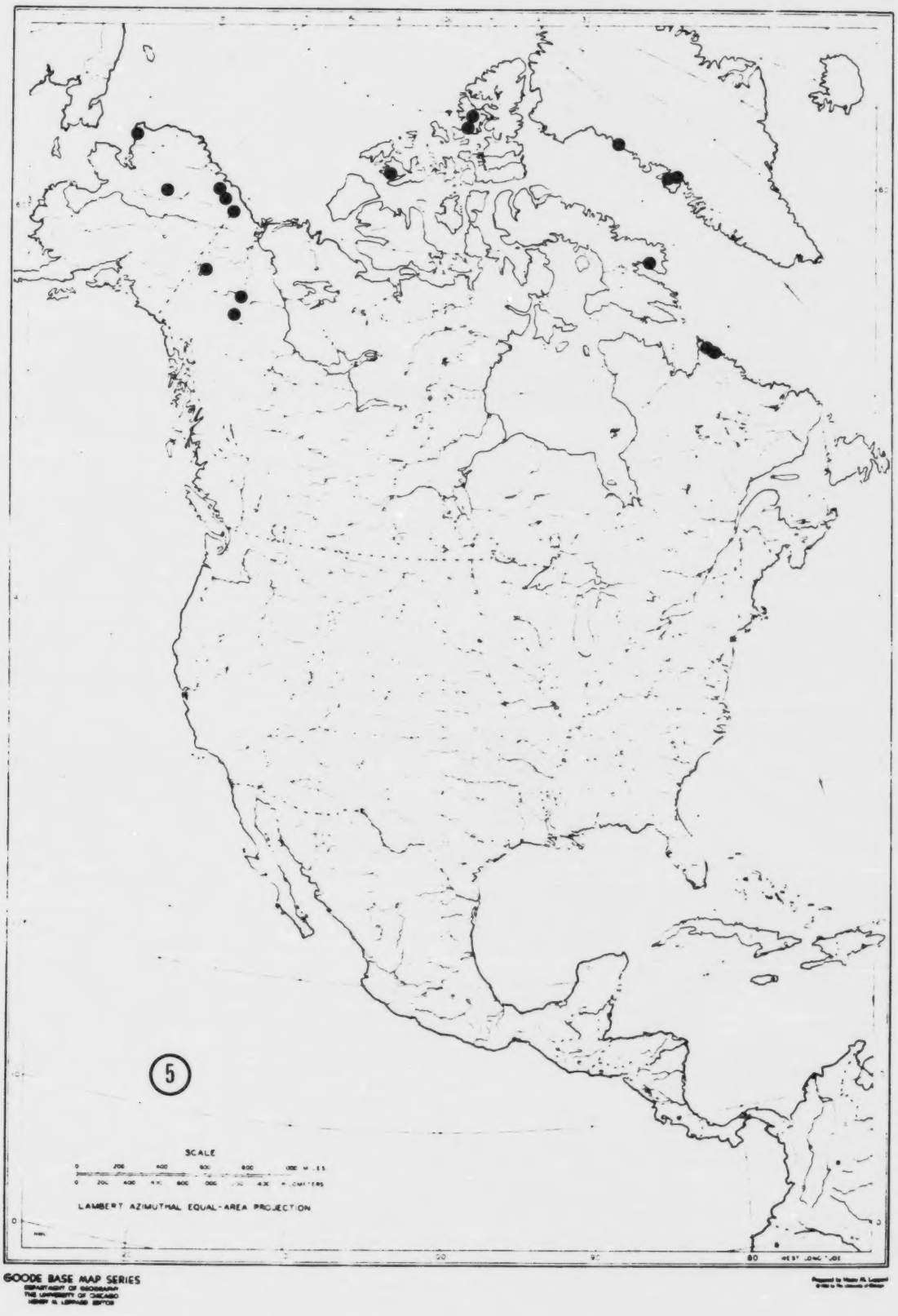


Figure 5. The North American distribution of *Oligotrichum falcatum* (adapted from Long, 1985).

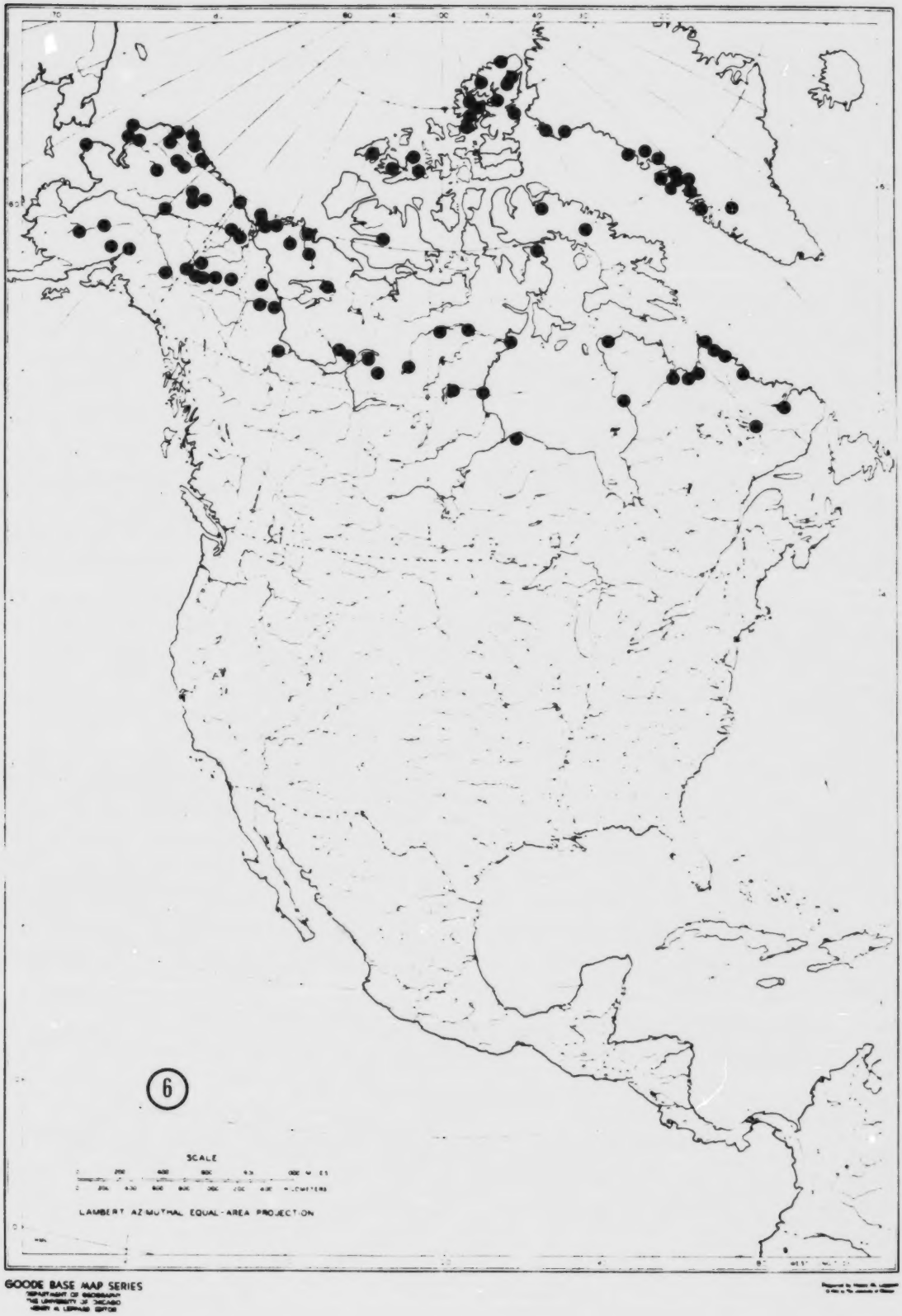


Figure 6. The North American distribution of *Polytrichum hyperboreum* (adapted from Long, 1985).

Figure 7. The North American distribution of *Didymodon asperifolius* (expanded from Schofield, 1972).

due to undercollecting. Ten of the arctic species reach their southern limits of eastern North American distribution in the Torngat:

Arctoa anderssonii
Bryum calophyllum
Campylium arcticum
Cnestrum alpestre
Cyrtomnium hymenophyllum
Oligotrichum falcatum (Figure 5)
Polytrichum swartzii
Psilopilum cavifolium
Rhizomnium andrewsianum
Timmia sibirica

Of the 16 arctic species that are not at their southern limit in the Torngat, nine are essentially continuously distributed between the Torngat and their southernmost stations:

Aplodon wormskioldii
Aulacomnium turgidum
Cinclidium subrotundum
Desmatodon latifolius
Dicranella crispa
Drepanocladus badius
Polytrichum hyperboreum (Figure 6)
Psilopilum laevigatum
Ulota curvifolia

The remaining seven species have discontinuous distributions in eastern North America, and are known from the Torngat and areas north, but also occur disjunctively in northern Newfoundland (Hedderson, 1984):

Bryum arcticum
Bryum longisetum
Bryum purpurascens
Desmatodon leucostoma
Didymodon asperifolius (Figure 7)
Scorpidium turgescens
Trichostomum arcticum

The Montane Element. This element comprises the 33 species (15% of the bryoflora) which occur solely in montane regions of the continent. All of the species in this category which occur outside North America show a similar restriction in the rest of their world range.

The majority of the montane species (27) are disjunct between eastern and western North America — generally with a broader range in the western part of the continent. Fourteen of the montane species disjunct in North America are known elsewhere in eastern North America from the Gulf of St. Lawrence region, far to the south (Belland, 1985):

Andreaea nivalis
Grimmia incurva
Grimmia tenerrima
Hydrogrimmia mollis
Hygrohypnum smithii
Kiaeria falcata
Lescuraea radicosa
Lescuraea saxicola
Oligotrichum hercynicum
Pseudoleskeella tectorum
Scapania spitzbergensis (Figure 8)
Trichodon cylindricus

Six species in this category are disjunct in eastern North America from the Torngat to both the Gulf of St. Lawrence (to the South) and northern Ellesmere (to the North):

Campylopus schimperi (Figure 9)
Coscinodon cribrosus
Hygrohypnum alpestre
Mielichhoferia elongata
Mielichhoferia mielichhoferi
Tortula norvegica

A single species (*Marsupella revoluta*) occurs north of the Torngat (on nearby Baffin Island) but not further south. Five of the montane species disjunct between eastern and western North America are known in the east only from the Torngat:

Anastrophyllum assimile (Figure 10)
Asterella gracilis
Barbula michiganensis
Grimmia elongata
Hygrohypnum cochlearifolium

Asterella gracilis and *Barbula michiganensis* have intermediate populations in the Great Lakes area.

Eight of the montane species are known on the North American continent only from the east. I have included in this group four species, apparently endemic, which remain undescribed. Of the remaining four species in this category, two (*Grimmia funalis* and *Lophozia cavifolia*) are known only from the Torngat, and two (*Brachythecium glaciale*, *Grimmia atrata*) also occur in the Gulf of St. Lawrence region. All four of these occur in montane regions of Europe and Asia.

Discussion

Approximately 65% of the Torngat bryoflora is transcontinental and occurs both north and south of the region. The remainder comprises phytogeographically "interesting" species, including those at latitudinal limits of distribution, disjuncts, and endemics, and it is the significance of these groups of species that I will address here.

Species at latitudinal limits of distribution

Fourteen percent of the species known from the Torngat reach latitudinal limits there. With the exception of three arctic-montane species, this group is comprised entirely of boreal and arctic elements. It has been suggested that northern Quebec-Labrador is an important transitional zone between arctic and boreal elements in both the bryophyte (Brassard and Weber, 1978) and vascular floras (Morriset et al., 1983) of eastern North America. Brassard and Weber (1978) list approximately 75 moss species of essentially boreal affinity which have northern limits in Labrador. To date only 17 of these boreal species are known to have limits in the Torngat, while the remainder have their limits farther south. While this suggests the Torngat do not constitute an important limit for boreal species, it must be pointed out that potentially important habitats for these (eg. low altitude wetlands, willow thickets) are among the bryologically least known habitats in the area. Continued work may well show the Torngat to be more important in this respect than presently apparent.

Figure 8. The North American distribution of *Scapania spitzbergensis* (expanded from Schuster, 1983).

Figure 9. The North American distribution of *Campylopus schimperi* (expanded from Frahm, 1980).

Figure 10. The North American distribution of *Anastrophyllum assimile* (expanded from Horton, 1977).

The Torngat appear to be a more significant limit for arctic species. The ten arctic species that appear to have southern limits in the Torngat represent more than half of the total species listed by Brassard and Weber (1978) as having a southern limit in Labrador. Arctic species at their southern limit in the study area are predominantly of high, rather than low arctic affinity and include most of the representatives of that element (Schofield, 1972, 1980; Steere, 1965) known to occur in eastern North America. Additional collections in the Torngat, particularly in calcareous regions that thus far remain virtually unexplored, will undoubtedly add to this high arctic element.

Disjuncts and endemics

Twenty one percent of the Torngat bryoflora is disjunct from western North America, disjunct from montane areas of Europe and/or Asia, or endemic to the Torngat. Eleven of the disjuncts are species of boreal affinity that reach their northern limit in the Torngat. These probably survived Pleistocene glaciations further south, having dispersed postglacially to reach their present limits (Belland, 1983, 1984; Brassard, 1983). The rest of the disjuncts are of montane or arctic-montane affinity. The extreme geographical isolation of some of these, particularly the montane species, strongly suggests that their Torngat occurrences are relictual. The ice-free areas believed to have existed in the Torngat during the Pleistocene would likely have been able to support most of these disjuncts since virtually all occur in habitats that would have been readily available in such refugia.

The refugial status of the Torngat is supported by the occurrence there of an endemic moss element. Low levels of bryophyte endemism are by far the rule for most areas of North America. The extremely ancient and bryologically well explored Appalachians, for example, have only twelve endemic mosses (Schofield, 1980), many of which are only weak segregates from more widespread species (Anderson & Zander, 1973). In this light, the finding of four, markedly segregated, moss endemics in the Torngat seems particularly significant, especially since only two complete field seasons have been spent in the area. Whether these endemics are relicts of an ancient flora, or represent local speciation, their presence implies the continuous availability of land surfaces for very long periods of time.

The existence of Pleistocene refugia in northern Labrador may have had a major influence on the composition of the bryophyte flora of eastern North America, and the implications for understanding the history of the disjunct elements are particularly great. In eastern North America other major centers for disjunct bryophytes are the Gulf of St. Lawrence region and western Greenland (Belland, 1983, 1984; Brassard, 1983, 1984; Schuster, 1983; Schuster & Damsholt, 1974), and the possibility exists that parts of both these disjunct bryofloras were derived by dispersal from a Torngat center. It seems pertinent to note here that many of the disjunct bryophytes that are very rare and localized in both Greenland and the Gulf of St. Lawrence area are extremely common in the Torngat (e.g. ***Andreaea nivalis***, ***Campylopus schimperi***, ***Hydrogrimmia mollis***, ***Kiaeria falcata***, ***Scapania spitzbergensis***).

A major objection to the idea of postglacial dispersal from the Torngat to either Greenland or the Gulf of St. Lawrence is the apparent lack of intermediate populations. This, coupled with the then seeming absence of many critical disjuncts from the Torngat, was in part responsible for the conclusion by both Brassard (1984) and Belland (1984) that migration from the Torngat Mountains was of minimal importance to the bryoflora of the Gulf of St. Lawrence. While the second objection has largely been removed by recent work, the first still remains. It must be noted however that areas intervening between the Torngat and both Greenland and the Gulf of St. Lawrence are still largely unknown bryologically. This is particularly true of the latter case (i.e. between the Torngat and the Gulf of St. Lawrence), and a complete evaluation of the influence of possible Torngat refugia on the Gulf bryoflora must await bryological exploration of the vast territory of north and north-central Labrador. The coastal ranges of the Kaumajet and Kigplait Mountains, as well as the higher parts of the Mealy Mountains, constitute critical areas in this respect, and continued bryological exploration of Labrador would do well to concentrate on these.

Acknowledgments

I wish first to thank my supervisor, Dr. G.R. Brassard, for invaluable guidance and support through most aspects of this study. Very capable assistance in the field was provided by Ms. Holly Hogan. The members of the Memorial University Geography field party — Dr. R..J. Rogerson, Mr. Trevor Bell, Ms. Jackie Gallagher, Mr. Bob Rowsell, and Ms. Janet Russell — provided logistic assistance and very welcome companionship in the field. Special thanks are due Captain Piercy, the officers and crew of the Canadian Coast Guard Ship, Sir John Franklin, for transport to Nachvak Fiord and assistance in establishing base camp. Ms. Christine Campbell graciously assisted with preparation of the manuscript. Research was funded by Northern Scientific Training Program in 1983 and 1986, and by Natural Sciences and Engineering Council of Canada Grants (A-6683 and N-0005) to G.R. Brassard.

References

Anderson, L.E. & R.H. Zander. 1973. The mosses of the southern Blue Ridge Province and their phytogeographic relationships. J. Elisha Mitchell Sci. Soc. 89: 15–60.

Banfield, C.E. 1981. The climatic environment of Newfoundland. pp. 83–153 In A.G. Macpherson & J.B. Macpherson (eds.), The Natural Environment of Newfoundland Past and Present. Dept. Geogr. Memorial University of Newfoundland, St. John's.

Belland, R.J. 1983. A late snow bed bryophyte community in western Newfoundland, Canada. Can. J. Bot. 61: 218–223.

_____ 1984. The disjunct bryophyte element of the Gulf of St. Lawrence region: glacial and postglacial dispersal and migrational histories. Ph.D. thesis Memorial University of Newfoundland, St. John's.

Brassard, G.R. 1980. The moss genus *Timmia*. 2. Section Timmiaurea. Lindbergia 6: 129–136.

_____ 1983. Bryogeography, with special reference to mosses. pp. 361–384 In G.R. South (ed.), Biogeography and Ecology of the Island of Newfoundland. Junk, The Hague.

_____ 1984. The bryogeographical isolation of the island of Newfoundland, Canada. Bryologist 87: 56–65.

_____ & D.P. Weber. 1978. The mosses of Labrador, Canada. Can. J. Bot. 56: 441–466.

Bremer, B.A. 1980a. A taxonomic revision of *Schistidium* (Grimmiaceae, Bryophyta) 1. Lindbergia 6: 1–16.

_____ 1980b. A taxonomic revision of *Schistidium* (Grimmiaceae, Bryophyta) 2. Lindbergia 6: 89–117.

_____ 1981. A taxonomic revision of *Schistidium* (Grimmiaceae, Bryophyta) 3. Lindbergia 7: 73–90.

Crum, H.A. & L.E. Anderson. 1981. Mosses of Eastern North America. Columbia University Press, New York.

_____, W.C. Steere & L.E. Anderson. 1973. A new list of the mosses of North America north of Mexico. Bryologist 76: 85–130.

Evans, D.J.A. & R.J. Rogerson. 1986. Glacial geomorphology and chronology in the Selamiut Range - Nachvak Fiord area, Labrador. Can. J. Earth Sciences 23: 66-76.

Frahm, J.P. 1980. Synopsis of the genus *Campylopus* in North America, north of Mexico. Bryologist 83: 570-588.

Hedderson, T.A. 1984. The presence and importance of the northern moss element in northernmost Newfoundland. B.Sc. thesis, Memorial University of Newfoundland, St. John's.

_____ & G.R. Brassard. 1986. The bryophytes of Nachvak, northern Labrador, with additional records from Saglek. Can. J. Bot. 64: 2028-2036.

Horton, D.G. 1977. *Anastrophyllum assimile* and *Marsupella revoluta* new to the interior of North America. Can. J. Bot. 55: 2479-2484.

_____ 1982. A revision of the Encalyptaceae (Musci), with particular reference to the North American taxa. Part I. J. Hattori Bot. Lab. 53: 365-418.

_____ 1983. A revision of the Encalyptaceae (Musci), with particular reference to the North American taxa. Part II. J. Hattori Bot. Lab. 54: 353-532.

Ireland, R.R. 1969. A taxonomic revision of the genus *Plagiothecium* for North America, north of Mexico. Nat. Mus. Can. Publ. Bot. 1.

_____ 1982. Moss Flora of the Maritime Provinces. Nat. Mus. Can. Publ. Bot. 13.

Ives, J.D. 1974. Biological refugia and the nunatak hypothesis. pp. 605-636 In J.D. Ives & R.G. Barry (eds.) Arctic and Alpine Environments. Methuen, London.

_____ 1978. The maximum extent of the Laurentide ice sheet along the east coast of North America during the last glaciation. Arctic 31: 24-53.

Lawton, E. 1971. Moss Flora of the Pacific Northwest. Hattori Botanical Laboratory, Nichinan, Japan.

Lewinsky, J. 1974. The genus *Leskeella* and *Pseudoleskeella* in Greenland. Bryologist 77: 601-611.

Long, D.G. 1985. Illustrated Moss Flora of Arctic North America and Greenland. 1. Polytrichaceae. Medd. om Grønland, Bioscience 17: 9-57.

Morriset, P., S. Payette & J. Deshaye. 1983. The vascular flora of the northern Quebec-Labrador peninsula: phytogeographic structure with respect to the tree line. Nordicana 47: 141-152.

Payette, S. 1983. The forest tundra and present tree-line of the Northern Quebec-Labrador Peninsula. Nordicana 47: 3-23.

Rousseau, C. 1974. Géographie Floristique du Québec-Labrador. Presses Univ. Laval, Québec.

Schofield, W.B. 1972. Bryology in arctic and boreal North America and Greenland. Can. J. Bot. 50: 1111-1133.

_____ 1980. Phytogeography of the mosses of North America (north of Mexico). pp. 131-170, In R.J. Taylor and A.E. Leviton (eds.), The Mosses of North America. Pacific Division of the American Association for the Advancement of Science.

_____ & H.A. Crum. 1972. Disjunctions in bryophytes. Ann. Missouri Bot. Gard. 59: 174-202.

Schuster, R.M. 1966-1980. The Hepaticae and Anthocerotae of North America east of the Hundredth Meridian. Vol. I-IV. Columbia University Press, New York.

_____ 1983. Phytogeography of the bryophyta. In R.M. Schuster (ed.) New Manual of Bryology. Hattori Botanical Laboratory, Nichinan, Japan.

Shaw, J. 1982. *Pohlia* Hedw. (Musci) in North and Central America and the West Indies. Cont. Univ. Mich. Herb. 15: 219-295.

Sjödin, A. 1980. Index to distribution maps of bryophytes 1887-1975. I. Musci. Vaxtekologiska studier 11. Uppsala.

_____ 1980b. Index to distribution maps of bryophytes 1887-1975. II. Hepaticae. Vaxtekologiska studier 12. Uppsala.

Steere, W.C. 1965. The boreal bryophyte flora as affected by Quaternary Glaciation. pp. 485-495, In H.E. Wright Jr. & D.G. Frey (eds.) The Quaternary of the United States. Princeton University Press, Princeton, N.J.

_____ 1978. The Mosses of Arctic Alaska. Vaduz. J. Cramer.

Stotler, R. & B. Crandall-Stotler. 1977. A checklist of the liverworts and hornworts of North America. Bryologist 80: 405-428.

Vitt, D.H. 1970. The family Orthotrichaceae (Musci) in North America north of Mexico. Ph.D. thesis. Univ. of Michigan, Ann Arbor.

HERBIVORY, LESSER SNOW GEESE AND THE PRODUCTION OF SALTMARSH VEGETATION, NORTHERN MANITOBA

David S. Hik

Department of Botany, University of Toronto, Toronto, Ontario M5S 1A1

Level: Master's

Abstract

A lively debate has taken place as to whether herbivory can lead to increased net primary production of forage plants beyond that of ungrazed plants. The herbivore-optimization model predicts that net primary production of grazed plants increases at low to moderate levels of herbivory, but at higher levels of grazing, production falls.

Captive lesser snow goose goslings have grazed experimental plots of a grass and sedge community in a saltmarsh at La Pérouse Bay, Manitoba, for different time periods. The above-ground biomass in all plots was measured at the start of the experiment, immediately after the period of grazing, and 36 days later. After grazing, the plots were exclosed. Faeces remained on the plots.

Thirty-six days after grazing, the standing crop of above-ground biomass was highest at intermediate period of grazing, such that the net above-ground primary production far exceeded that of ungrazed plots. As the period of grazing was increased further, there was a gradual decline in production. The general form of the experimental curve at 36 days follows that predicted by the herbivore-optimization model. The plant-herbivore interaction is "successful" because of the ability of the graminoid plants to respond rapidly to the availability of nutrients in goose faeces.

Key words: Net primary production, herbivore-optimization model, saltmarsh vegetation, lesser snow geese, south Hudson Bay coast.

Résumé

Un débat animé s'est déroulé pour savoir si les plantes fourragères broutées fournissaient une plus forte production primaire que les plantes non broutées. Le modèle élaboré permet de conclure que la production nette primaire des plantes broutées augmente si leur broutage est faible ou modéré, mais qu'elle diminue fortement en cas de broutage intensif.

L'auteur a fait pâturer des oisons (petite oie blanche) captifs dans des parcelles expérimentales d'herbes et de carex d'un marécage salé de la baie de La Pérouse, au Manitoba. Il a

mésuré la biomasse aérienne de toutes les parcelles avant l'expérience, immédiatement après sa fin, et trente-six jours plus tard. Les déjections des oisons restaient sur le sol des parcelles. L'expérience a été répétée un certain nombre de fois au cours de l'été.

Trente-six jours après broutage, ce sont les parcelles modérément broutées qui avaient la biomasse aérienne la plus forte, et de façon telle que la production primaire aérienne dépassait de beaucoup celle des parcelles non broutées. L'intensification du broutage au delà du niveau intermédiaire entraînait un déclin graduel de la production. La forme générale des courbes établies par l'expérimentation 36 jours après sa fin sont conformes à celles tracées grâce au modèle d'optimalisation du broutage. Les interactions entre plantes et herbivores sont favorables, en raison de la capacité des plantes herbeuses à réagir rapidement à l'apport des nutriments contenus dans les déjections des herbivores.

Mots-clés: Production primaire nette, végétation halophile, petite oie blanche, modèle d'optimalisation du broutage, littoral méridional de la baie d'Hudson.

Introduction

Ever since Owen and Weigert (1976) proposed that herbivores may increase the fitness of the plants they consume, a lively debate has ensued regarding the validity of this proposal. The topic that has aroused most interest is whether grazing increases the net productivity of forage species (see McNaughton, 1979, 1983). Most of the theoretical contributions to this debate have been concerned with the existence of coevolved mutualisms between grazers and forage plants (Stenseth, 1978, 1983; Owen and Wiegert, 1981, 1982a,b; Herrera, 1982, 1985; Thompson and Uttley, 1982; Silvertown, 1982); experimental evidence in support of the hypotheses has trailed far behind. However, McNaughton (1976, 1979, 1984, 1985) has amassed considerable evidence suggesting that, on the Serengeti plains, plants exhibit "a compensatory growth response" to grazing by large African ungulates.

The response of forage plants to grazing can be described in terms of the herbivore-optimization model (Fig. 1; also see McNaughton, 1983; Belsky, 1986; Jefferies, 1987). The essence of this model is that, at some optimal level of grazing, net primary production will be significantly increased over the control (ungrazed) plants. In a recent review of this literature, Belsky (1986) suggested that all of the studies that have reported results which are purported to fit the type of herbivore-optimization curve in Figure 1 are deficient in some respect, and that their conclusions, therefore, may not be valid. In particular, Belsky is critical of the experimental designs and measurements of production.

Despite the problems surrounding experiments which have been conducted on natural populations, there is good evidence that, under controlled laboratory conditions, clipping experiments may result in enhanced net primary production (McNaughton *et al.*, 1983; Wallace *et al.*, 1985), and increased production has also been reported in some agricultural crop species (see Belsky, 1986). These results suggest that, under suitable conditions, enhanced primary production may occur in natural populations. It is necessary, however, to determine the mechanisms that account for any increased productivity under grazed conditions. These include the

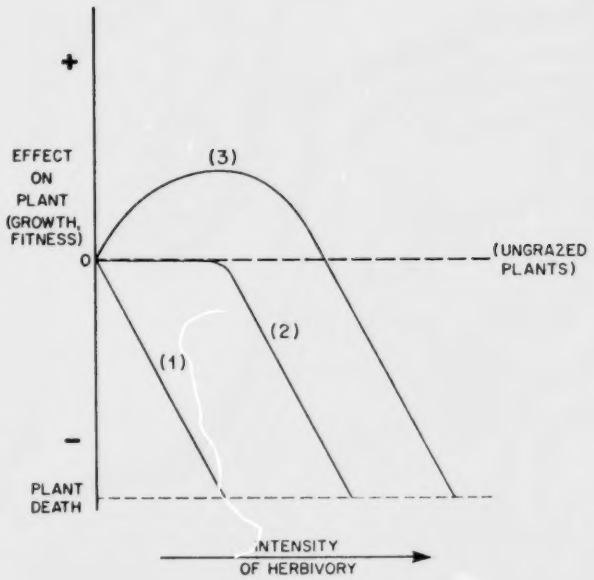


Figure 1. Three possible effects of herbivory on plant fitness. 1) Decline in fitness as the intensity of herbivory increases; 2) Compensation by the plants up to a threshold level of herbivory, after which fitness decreases; 3) Herbivore-optimization curve. Fitness of the plants increases at moderate levels of herbivory, but decreases as the intensity of herbivory increases. (Modified after McNaughton, 1983; Jefferies, 1987).

presence of adequate supplies of water and nutrients for regrowth, and sufficient time during the growing season for the plants to recover from grazing.

These conditions are associated with the type of herbivory practised by lesser snow geese (*Chen caerulescens caerulescens*) grazing on salt-marsh vegetation at La Pérouse Bay. The characteristics of the vegetation of this saltmarsh and the effects of grazing by the geese have been described in detail by Jefferies *et al.* (1979), Cargill and Jefferies (1984a,b), Jefferies *et al.* (1984), Bazely and Jefferies (1985, 1986), and Jefferies (1987). In this paper, I present experimental evidence which suggests that moderate levels of grazing by snow geese increase the production of the saltmarsh vegetation, following the predictions of the herbivore-optimization model.

Methods

The study was conducted at the Queen's University Tundra Biology Station at La Pérouse Bay, 30 km east of Churchill, Manitoba (58°24′N, 94°24′W). The breeding colony of lesser snow geese at this site has been studied since 1968 (see Cooke *et al.*, 1982), and the colony has increased from 1200 breeding pairs initially, to about 7000 pairs in 1986 (Cooke and Rockwell, unpublished data). Although the geese arrive at the colony in mid-May, they do not begin to graze the above-ground vegetation until the beginning of the growing season in mid-June. Following the hatch of goslings in mid- to late June, the saltmarsh supports 30,000 to 40,000 geese for 6 to 8 weeks until the goslings fledge.

On 22 June 1986, captive lesser snow goose goslings were permitted to graze 1m × 1m plots for six periods of time; 150, 120, 90, 60, 30, and 0 (control) minutes. The vegetation of the plots consisted predominantly of *Puccinellia phryganodes* (Trin.) Scribn. and Merr., a stoloniferous grass, but also contained smaller quantities of *Carex subspathacea* Wormskj., a rhizomatous sedge, and several dicotyledonous plants including *Plantago maritima* Torr., *Salicornia europaea* agg., and *Potentilla egedii* Wormsk. Each treatment (period of grazing) was replicated four times. For each treatment, four goslings (aged 6 days and a mean weight of 127g ± 7g SEM) were assigned randomly to one of the four 1m × 1m replicate plots and permitted to graze for the appropriate length of time. At the end of the experiments, all treatments were exclosed with chicken wire to protect the plots from subsequent grazing by wild geese.

Vegetation was sampled at random by removing 7.5 × 7.5 cm turves before grazing, immediately following grazing, and 36 days following the experiment. Turves were returned to the lab, where above-ground biomass was clipped at ground level. The clippings were washed and then dried for 48 hr before weighing.

Goose faeces were not removed from the plots, but the droppings in each plot were counted, and 6 droppings chosen at random were removed and their dry weight determined. In addition, the droppings deposited during the period 10 to 19 June were counted in six 10m × 10m quadrats on the grazing flats. This permitted the number and nitrogen content of droppings under natural conditions to be compared with experimental levels. Nitrogen content of the faeces was estimated from Bazely and Jefferies (1985).

Results

Figure 2 shows that the final standing crop is significantly greater at intermediate periods of grazing ($F[5,54] = 2.749$, $p = 0.0276$). At 36 days, the above-ground biomass of these grazed plots far exceeded that of ungrazed plots. However, as the period of grazing increased, the above-ground biomass decreased.

Net above-ground primary production is calculated as the difference between final standing crop (36 days regrowth), and standing crop following grazing (Fig. 3). The control plots had a significantly lower production than any of the grazed plots ($F[5,18] = 6.851$, $p = 0.001$).

The total dry weight of the droppings deposited by the birds in each experiment, as well as under field conditions, is given in Table 1. Since no droppings were collected from the field plots, these values are only estimates. The total dry weight of the droppings in the field plots is most similar to the dry weight of droppings deposited in the 60-minute grazing plot, which had the greatest production. Grazing for this period of time and the input of nitrogen from the faeces are associated with the largest increase in net primary production.

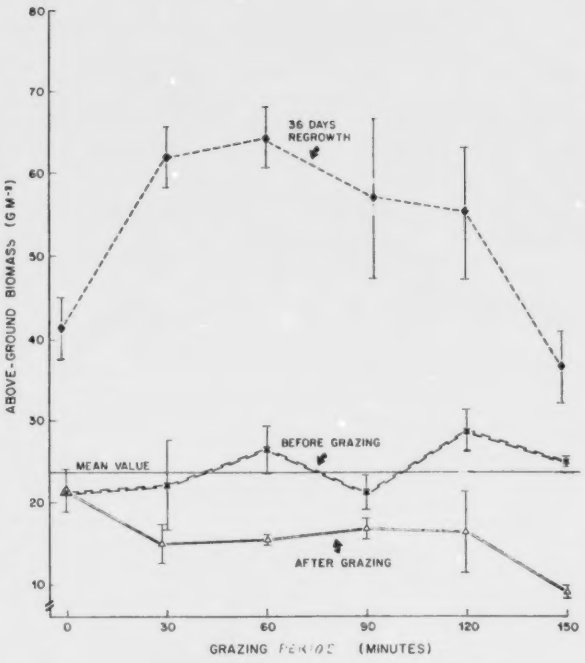


Figure 2. Standing crop (dwt. g/m^{-2}) in experimental plots which have been grazed by lesser snow goose goslings at La Pérouse Bay. Before grazing (×); immediately after grazing (▲); 36 days after grazing (◆). Values plotted are mean ± SEM (n = 4).

TABLE 1
Total dry weight (g dwt. m^{-2}) and estimates of nitrogen content of faeces deposited in grazed plots for each experimental treatment and under natural field conditions at La Pérouse Bay (values are mean ± S.E.M.; nitrogen content determined from Bazely and Jefferies, 1985)

Treatment*	g dwt. faeces m^{-2}	g N m^{-2}
0 min	0	0
30 min	0.63±.05	0.01
60 min	1.11±.08	0.02
90 min	2.45±.19	0.04
120 min	4.82±.37	0.09
150 min	8.06±.61	0.15
field level** (9 days)	1.42±.50	0.03

*based on 6 randomly collected droppings
**based on estimates from Cargill and Jefferies (1984a)

Discussion

The results of this study are consistent with the predictions of the herbivore-optimization model described by McNaughton (1979). Although different mechanisms may account for the observed, or suspected, compensatory response to grazing (McNaughton, 1979; Dyer, 1980; Owen and Wiegert, 1981), the mechanism operating in the snow goose saltmarsh system appears to be linked to the availability of nitrogen for plant growth. Goose faeces provide a readily available source of nitrogen in an otherwise nitrogen-limited environment, and this source significantly boosts the production of the grazed sward (Cargill and Jefferies, 1984a,b; Bazely and Jefferies, 1985). When

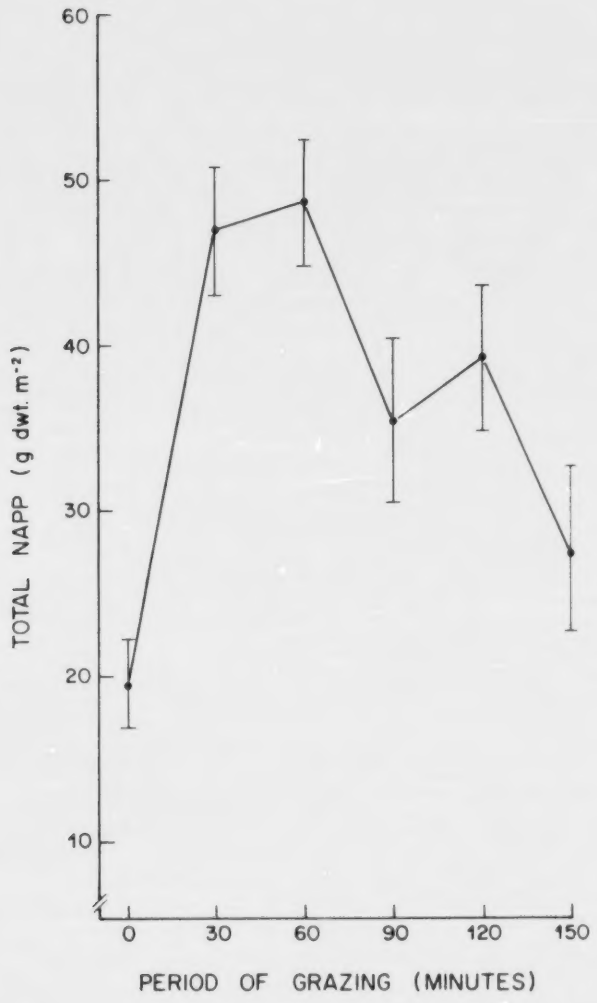


Figure 3. Total net above-ground primary production, NAPP (dwt. g/m^{-2}) of experimental plots grazed by lesser snow goose goslings, after 36 days of regrowth. Values plotted are mean ± SEM (n = 4).

nitrogen fertilizer or fresh goose faeces were applied to plots containing *Carex* and *Puccinellia*, production was greatly increased over that of similar untreated plots.

In other goose grazed communities in the Arctic, production has not been directly monitored, but similar effects of grazing on net primary production may exist. Greater snow geese (Giroux *et al.*, 1984), Canada geese (Sedinger and Raveling, 1984), and Barnacle geese (Prop *et al.*, 1984) all forage in vegetation similar to that of La Pérouse Bay. Herbivory by other large grazers, such as Musk-oxen (Henry *et al.* 1987), may also lead to compensatory growth in grazed Arctic plants. All of these systems tend to be dominated by a single herbivore grazing on extensive swards of graminoids. More importantly, these areas are nitrogen-limited (see Cargill and Jefferies, 1984b), and the vegetation would show a rapid growth response to an increased turnover of nitrogen. As the migratory habits of many Arctic grazers reduce the grazing pressure on a grazed sward for at least a part of the short growing season, the vegetation can recover from the effects of the removal of tissue in sites where there is a supply of nitrogen.

Many animals graze on grasses and sedges, but in only a few cases has compensatory plant growth been reported. For example, giant tortoises grazing on Aldabra Atoll are forced to seek shade during the day and as a result most droppings are deposited under trees, not on the grazing swards (Gibson and Phillipson, 1983). In the Serengeti, where McNaughton (1979, 1984, 1985) has reported extensive regrowth of plants following defoliation, water limitations beyond the control of either the herbivore or the plants may be important in limiting production. Because of these and other confounding effects, there may be only a few localities where conditions approach those required by the model.

The implications of the herbivore-optimization model on the distribution of lesser snow geese on the breeding grounds are considerable. Clearly heavy grazing leads to a reduction in the amount of forage available. The geese influence the production of the vegetation, which in turn influences the distribution of the geese. The effects of grazing on saltmarsh vegetation can be explained by a positive-feedback model (Jefferies *et al.*, 1984), which accounts for the experimental results.

Acknowledgments

I would like to thank Dr. R.L. Jefferies for his guidance and support during this study. Janet Curran, Peter Kotanen, Joan Montagnes, and Helen Sadul provided many helpful suggestions and assisted in the data collection. The students and staff at the Queen's University Tundra Biology Station and the Churchill Northern Studies Centre provided valuable logistical support. Funding for this project was provided in part by the Natural Sciences and Engineering Council of Canada, the Canadian Wildlife Service (Environment Canada), and an Orville Erikson Memorial Scholarship from the Canadian Wildlife Foundation.

References

Bazely, D.R. and R.L. Jefferies. 1985. Goose faeces: a source of nitrogen for plant growth in a grazed salt marsh. Journal of Applied Ecology 22: 693–703.

Bazely, D.R. and R.L. Jefferies. 1986. Changes in the composition and production of saltmarsh plant communities in response to the removal of a grazer. Journal of Applied Ecology 74:(in press).

Belsky, A.J. 1986. Does herbivory benefit plants? A review of the evidence. American Naturalist 127: 870–892.

Cargill, S.M. and R.L. Jefferies. 1984a. The effects of grazing by lesser snow geese on the vegetation of a sub-Arctic salt marsh. Journal of Applied Ecology 21: 669–686.

Cargill, S.M. and R.L. Jefferies. 1984b. Nutrient limitation of primary production in a sub-Arctic salt marsh. Journal of Applied Ecology 21: 657–668.

Cooke, F., K.F. Abraham, J.C. Davies, C.S. Findlay, R.F. Healey, A. Sadura and R.J. Seguin. 1982. The La Pérouse Bay snow goose project: a 13-year report. Unpublished report on file at Queen's University and the Canadian Wildlife Service.

Dyer, M.L. 1980. Mammalian epidermal growth factor promotes plant growth. Proceedings National Academy Science (USA) 77: 4836–4837.

Gibson, C.W.D. and J. Phillipson. 1983. The primary production of Aldabra Atoll with reference to habitats used by giant tortoises. Philosophical Transactions of the Royal Society (London) B302: 167–199.

Giroux, J-F., Y. Bedard and J. Bedard. 1984. Habitat use by greater snow geese during the brood rearing period. Arctic 37: 155–160.

Henry, G., B. Freedman and J. Svoboda. 1987. Effects of fertilization on three tundra plant communities of a polar desert oasis. Canadian Journal of Botany (in press).

Herrera, C.M. 1982. Grasses, grazers, mutualism, and coevolution: a comment. Oikos 38: 254–258.

Herrera, C.M. 1985. Grass/grazer radiations: an interpretation of silica-body diversity. Oikos 45: 446–447.

Jefferies, R.L. 1987. Vegetational mosaics, plant-animal interactions, and resources for plant growth. In Plant Evolutionary Biology (Editors: Gottlieb, L.D. and Jain, S.K.). Chapman and Hall Ltd., London.

Jefferies, R.L., A. Jensen and K.F. Abraham. 1979. Vegetational development and the effect of geese on vegetation at La Pérouse Bay, Manitoba. Canadian Journal of Botany 57: 1439–1450.

Jefferies, R.L., D.R. Bazely and S.M. Cargill. 1984. Effects of grazing on tundra vegetation — a positive feedback model. Working Papers, second International Rangeland Conference, Adelaide, Australia. Day 1 — dynamics of range ecosystems.

McNaughton, S.J. 1976. Serengeti migratory Wildebeest: facilitation of energy flow by grazing. Science 191: 92–94.

McNaughton, S.J. 1979. Grazing as an optimization process: grass-ungulate relationships in the Serengeti. American Naturalist 113: 691–703.

McNaughton, S.J. 1983. Compensatory plant growth as a response to herbivory. Oikos 40: 329–336.

McNaughton, S.J. 1984. Grazing lawns: Animals in herds, plant form and coevolution. American Naturalist 124: 863–886.

McNaughton, S.J. 1985. Ecology of a grazing ecosystem: the Serengeti. Ecological Monographs 55: 259–294.

McNaughton, S.J., L.L. Wallace and M.B. Coughenour. 1983. Plant adaptation in an ecosystem context: effects of defoliation, nitrogen, and water on growth of an African C4 sedge. Ecology 64: 307–318.

Owen, D.F. and R.G. Wiegert. 1976. Do consumers maximize plant fitness? Oikos 27: 488–492.

Owen, D.F. and R.G. Wiegert. 1981. Mutualism between grasses and grazers: an evolutionary hypothesis. Oikos 36: 376–378.

Owen, D.F. and R.G. Wiegert. 1982a. Grasses and grazers: is there a mutualism? Oikos 38: 258–259.

Owen, D.F. and R.G. Wiegert. 1982b. Beating the walnut tree: more on grass/grazer mutualism. Oikos 39: 115–116.

Prop, J., M.R. van Eerden, R.H. Drent. 1984. Reproductive success of the Barnacle Goose, *Branta leucopsis*, in relation to food exploitation on the breeding grounds, western Spitsbergen. Norsk Polarinstitutt Skr. 181: 87–117.

Sedinger, J.S. and D.G. Raveling. 1984. Dietary selectivity in relation to food availability and quality of food for goslings of cackling geese. The Auk 101: 295–306.

Silvertown, J.W. 1982. No evolved mutualism between grasses and grazers. Oikos 38: 253–254.

Stenseth, N.C. 1978. Do grazers maximize individual plant fitness? Oikos 31: 299–306.

Stenseth, N.C. 1983. Grasses, grazers, mutualism and coevolution: a comment about handwaving in ecology. Oikos 41: 152–153.

Thompson, K. and M.G. Uttley. 1982. Do grasses benefit from grazing? Oikos 39: 113–115.

Wallace, L.L., S.J. McNaughton, and M.B. Coughenour. 1985. Effects of clipping and four levels of nitrogen on the gas exchange, growth, and production of two East African graminoids. American Journal of Botany 72: 222–230.

ASSESSING TRAIL CONDITIONS IN THE CANADIAN NORTH: A CASE STUDY IN TWO NATIONAL PARKS

Peter I. Hutchison

Department of Geography, Trent University, Peterborough, Ontario K9J 7B8

Level: Master's

Abstract

The recent increase in the number of people actively using the wilderness areas of northern national parks has meant that use and its consequent degradation must be measured and monitored. This paper is a progress report of a study assessing hiking-induced degradation on the Auriol Trail of Kluane National Park, Yukon, and the Chilkoot Trail of the proposed Chilkoot Trail National Historic Park, British Columbia. Quantifiable data were collected for trail condition, terrain type and backcountry use at numerous sites along each trail. The preliminary results indicate that terrain type can be an important factor in controlling degradation. The data assessed indicated that the existence of sub-surface ice may cause an increase in degradation through thermal processes. The generalizations developed during this study are applicable to future trial management.

Key words: Trail condition, Northern National Parks wilderness management, recreation impact.

Résumé

L'auteur a examiné, au cours de l'été de 1986, l'état du sentier de Nature du parc national Kluane dans le Sud-Est du Yukon, et le tracé de la piste de marche proposée pour le parc historique national Chilkoot, dans le Nord-Est de la Colombie-Britannique, afin d'évaluer les niveaux de dégradation des sols et de déterminer quel est le genre de terrain le plus fragile sous le piétinement.

Il a évalué les paramètres de dégradation (p. ex.: tassement du sol, usure, emprise) et ceux de nature du terrain (structure du sol, pente et genre de végétation) tout au long des sentiers, et les a corrélés afin de mettre en relief les genres de terrain les moins résistants au piétinement. La principale difficulté recontrée au cours de l'analyse a été de tracer la limite entre la dégradation et l'incidence d'environnement. Ce seuil diffère selon les parcs, en raison des différents objectifs de leurs gestionnaires et des préférences des utilisateurs.

Dans le parc Kluane, les amoureux de la Nature qui parcourent le sentier respectent une limite de dégradation plus basse que les marcheurs ne le feraient dans le parc historique national Chilkoot. Ces derniers fixent donc un seuil d'incidence élevé.

Mots-clés: Incidence d'environnement, conséquences de l'utilisation ludique, dégradation des sentiers, parcs nationaux nordiques.

Introduction

Recreational use of 'wilderness' areas has been increasing steadily in the 20th century (e.g. Jubenville 1978). It symbolizes the challenge of outdoor recreation and is the extreme example of dispersed recreation activity. A problem associated with this increase is a reduction in the quality and quantity of wilderness areas. For example McNamee (1986), on the subject of the future of Canadian Wilderness, says "Trends continue to point to an insidious and incremental degradation of Canadian Wilderness values and areas".

In the search for this 'perceived' wilderness, recreationalists are moving away from traditional areas (e.g. Banff National Park, Alta.), to the 'perceived' inaccessible Northern areas. The term 'perceived' is used because these areas (eg. the Yukon and Northwest Territories), are no longer the inaccessible places they were 20 years ago. Air and road transportation have improved to such an extent that the 'average' person can reach almost any destination if he or she so desires. The Alaska Highway now supports either good quality gravel or pavement along its entire route and, if the price is right, people can land on the flanks of Mt. Logan. This may appear a sweeping statement but the important point is that, with modern technology, formerly inaccessible wilderness environments can be reached at an ever-increasing rate. The extent of this is shown by the fact that tourism is now the second largest industry in the Northwest Territories, next only to mining and oil exploration (Parks Canada 1985a).

The increasing importance of tourism and recreation in the Canadian North can put pressure, whether for good (e.g. economically) or for bad (e.g. environmentally) on the areas where visitors concentrate. These areas tend to be the National Parks because of the promotion and publicity which their designation generates. Parallel with this overall increase in visitation is increased recreational use of the wilderness areas of the Parks, primarily in the form of hiking and camping. Hikers can use modern equipment (e.g. lightweight stoves and freeze-dried food) to increase accessibility of the wilderness. This has resulted in managers trying to minimize impacts on the physical and biological resources (Parsons and MacLeod 1980) through a variety of backcountry rules and regulations. Trails are the most noticeable indicator of impact of wilderness activity. They are an important management objective (Garland 1985) because their existence is not compatible with true 'wilderness' quality and can reduce its aesthetic value.

This paper is a progress report of a study examining the impact of one type of wilderness activity, namely hiking. It focuses on trail conditions in two national parks, 1) Kluane National Park (K.N.P.) in the southeastern part of the Yukon and 2) the proposed Chilkoot Trail National Historic Park (C.T.N.H.P.) in northeastern British Columbia, which is managed from Whitehorse, Yukon. It outlines the objectives, methods and preliminary results of the study and develops ideas regarding potential applications of the work.

Objectives

The objectives were, 1) to measure trail degradation along the Auriol trail in K.N.P. and the Canadian portion of the Chilkoot Trail in the C.T.N.H.P., and 2) to identify terrain types according to their susceptibility to hiking degradation.

The official approach to wilderness recreation in National Parks is to monitor the natural evolution of the park ecosystem and determine the effects of human activities (Parks Canada 1984). For effective wilderness management, it is essential to be able to predict where deterioration of the natural resource is likely to occur and then channel or regulate use accordingly. Therefore, when managing hikers, it is important to understand the trail condition (or level of degradation) so that protective actions can be taken on existing trails and improvements can be made for future trail design and location.

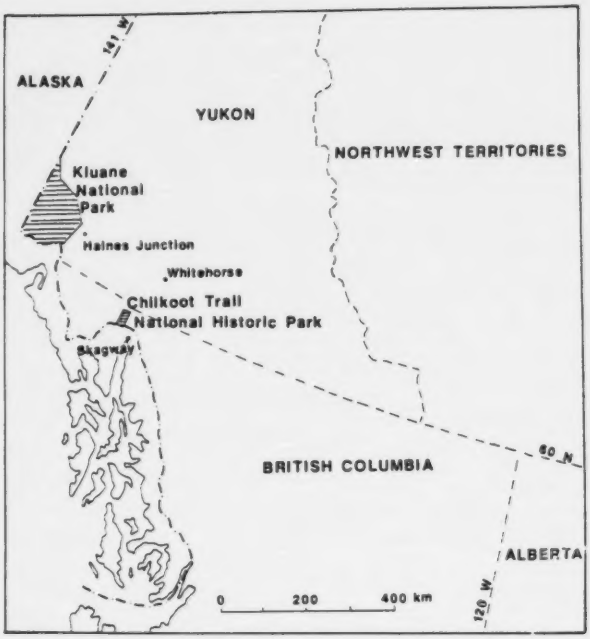


Figure 1. Regional setting of Kluane National Park and the proposed Chilkoot Trail National Historic Park

Knowledge of trail conditions is particularly important in the two parks involved in this study. In K.N.P., wilderness management is ranked first in the Problem Significance Rating (Parks Canada 1984). In the C.T.N.H.P. the trail itself is the major resource of the Park, reflecting its historical transport theme.

Background to the two trails

For the location of these trails see Figure 1.

The Auriol Trail, K.N.P.

Kluane National Park was designated to "protect for all time, an area of Canadian significance representative of the northern coast mountain areas" (Parks Canada 1980). Over 60% of the park is made up of the St. Elias Mountain range and is only accessible to experienced mountaineers. The remainder of the park is unglacierized and offers many hiking and backpacking opportunities.

The Auriol trail is situated in the east-central section of the unglaciated area. It is a 15 km. loop trail (see Figure 2). It is the only trail in the park which has been designed and located solely for recreational use (hiking and camping). It caters to all levels of hikers by containing a campground for those who wish to progress at a more leisurely pace, as well as providing access to higher reaches of the Park for the adventurous hiker. It is the most accessible trail to Haines Junction, the location of the K.N.P. visitor reception centre, and is the most heavily used trail in the Park (Personal communication 1986) with 197 hikers registering at the trail head

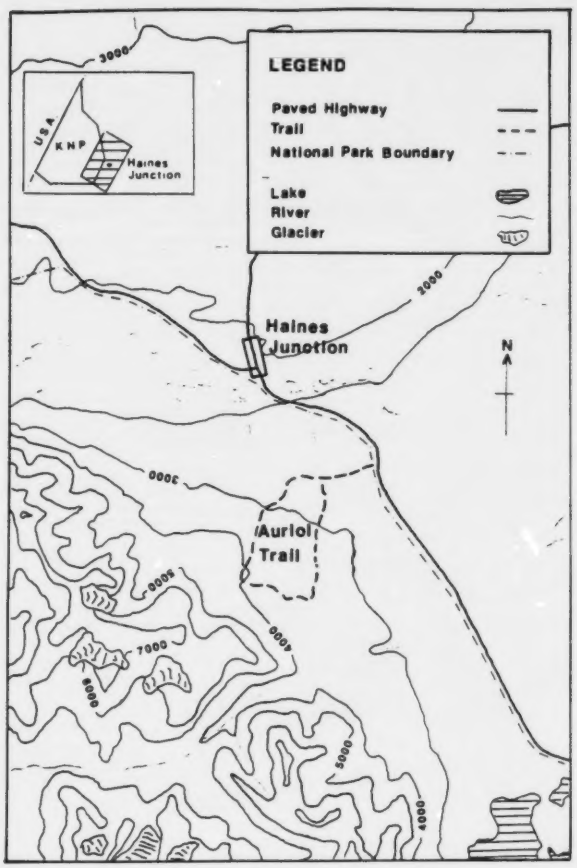


Figure 2. The location of the Auriol Trail in Kluane National Park

between June 7th and August 8th 1986 (dates of field season). This figure is not the true use statistic because a certain percentage of people do not register. In 1985 the guestimate correction index was 50% and although the 1986 visitor statistics have not been collated it is probable that the number of hikers who used the Auriol trail this summer is over 250.

The trail is mostly forest cut with some sections following a creek bed. It crosses three distinct vegetation zones: montane, sub-alpine and alpine. In the higher northern exposures, the presence of numerous leaning trees indicates that permafrost may be present (Parks Canada, 1985b).

The Chilkoot Trail, C.T.N.H.P.

The C.T.N.H.P. is to be designated to protect for all time the trail used by the prospectors of 1897–1898 en route to the Klondike gold fields. The trail and artifacts which litter the route are a significant historical resource.

The Chilkoot trail straddles the U.S.A.-Canadian border at the northern end of the Alaska panhandle. It extends from

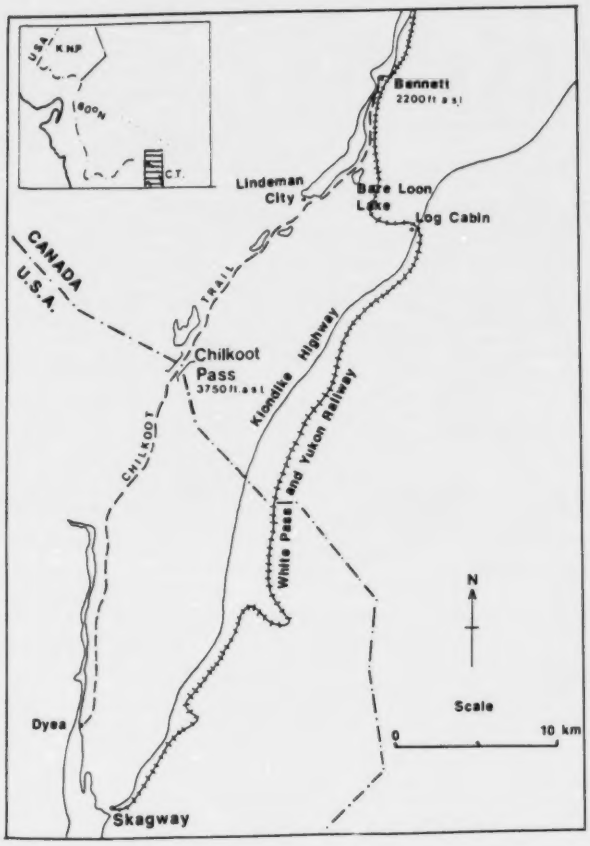


Figure 3. The location of the Chilkoot Trail.

Dyea, Alaska, to Bennett, B.C. (Figure 3). The Canadian portion of the Chilkoot trail is 26.6 km. long. Three vegetation zones exist along this section of the trail; Alpine, subalpine and Boreal forest. Because of the number of users of the trail (see Figure 4), terrain damage by hikers is becoming an important issue in the Management Planning Programme (Parks Canada 1986).

1973- 981	1980-2310
1974-1346	1981-2701
1975-1288	1982-2366
1976-1508	1983-1585
1977-1708	1984-1968
1978-1948	1985-1409
1979-2303	

(Parks Canada 1986)

Figure 4. Hiking use of the Chilkoot trail

Study Methods

Trail condition and erosion have been studied quite extensively in certain areas of Europe and North America. (see Liddle 1975). The general concensus is that trail condition is an interaction of the trail user, with geomorphological and climatic forces and the resistance of vegetation and soil (Coleman 1981). The condition is heavily influenced by the intensity of use but this is not a linear

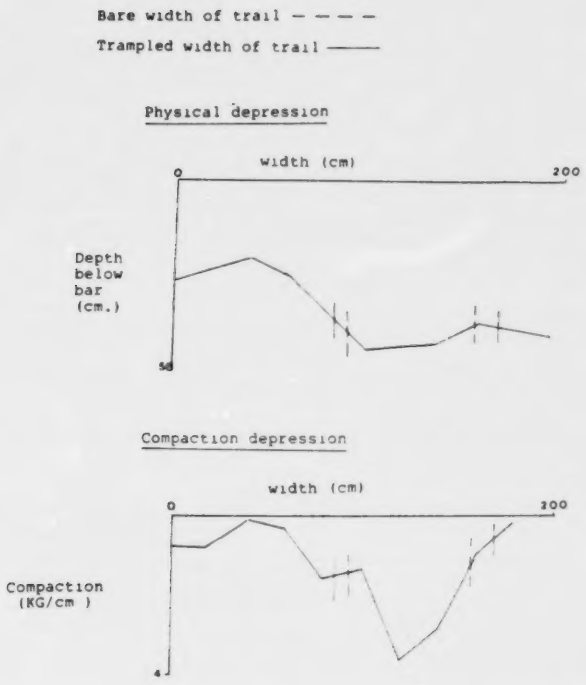


Figure 5. An example of 'physical' and 'compaction' depression. Auriol Trail : Site #114 : 31.07.86

relationship (Bayfield 1973) and the results of all studies stress the importance of 'unique' environments. For example Garland (1985), states that "Efficient path-engineering can only proceed from a full understanding of path erosion and the way in which environmental factors combine to influence it". Coleman (1981) developed a model which summarizes the typical study method and is given by:

$$Fr + Fg + R = Pm$$

where Fr = recreational forces
Fg = geomorphological forces
R = resistence
Pm = path morphometry

In the present study it was hypothesized that 'trail condition' (e.g. Pm) was a function of 'site terrain' (e.g. Fg and R) and 'backcountry use' (e.g. Fr). These three factors were assessed at a number of sample sites along each trail. The aim was to collect data from as many sites as possible within the time constraints rather than collect intensively from a limited number of sites (Welch and Churchill 1985). This was to ensure that conclusions drawn from the research were statistically sound as well as assessing the overall trail condition (Cole 1983). The methods for acquiring the data resulted from a literature search on the monitoring of wilderness/backcountry use (eg. Wall and Wright 1977). They were as follows.

1) Trail Condition

This involved measuring a number of variables which were indicators of trail degradation. These could be used in isolation or combined to produce a "degradation" index. The variables were chosen because their measurement was simple, quick and feasible on the types of terrain encountered. This ensured that the degradation index would be consistent for any site on either of the two trails. The five degradation variables were:-

1) Number of trails
2) Bare width
3) Trampled width
4) Trail 'physical' depression (cross-sectional area between the tread surface and a level bar placed between points either side of the trail). Each measurement was made at 20cm. intervals in order to standardize results. For example see Figure 5.
5) Trail 'compaction' depression (as for physical depression except measuring soil compaction). For example see Figure 5.
6) Stoniness

Ranked visual interpretation of trail degradation was also recorded. The criteria were walkability, surface deterioration, rutting, gullying, lateral erosion, and drainage.

2) Terrain type.

At each site where trail condition was measured the following variables were recorded:-

1) Aspect
2) Altitude
3) Slope of trail
4) Site position on slope
5) Depth to bedrock or active zone.
6) Soil texture
7) Soil drainage
8) Vegetation type and density (code)

Backcountry use

Along both trails, use was assumed to be constant. Thus differences in degradation along each trail were assumed to be terrain-related, not due to hikers' doubling back or concentrating at the start of the trail. The basis for this assumption was that: a) The Auriol trail is a loop trail and is hiked in one or two days according to hikers' desires. The possible pitfall which this study does not take into account is the direction that hikers take around the loop. Thus on slopes, degradation will be exaggerated if the majority of users are going downhill at that point and vice versa if the users are going uphill. b) The Chilkoot Trail is a line trail, with the majority of hikers travelling from the U.S.A. into Canada. The Canadian portion of the trail is beyond the Chilkoot Pass (International Boundary) – the logical point to turn around if hikers wish to backtrack. Therefore it seems safe to assume that the number of hikers is constant over sections of the trail studied. The main exception to this is that hikers turn off for Log Cabin (See Figure 3) at Bare Loon Lake and avoid the Bennett section of the trail. This is because hikers are often tired at this point and favour the shortest route back to Log Cabin rather than continue along the historical trail. The approximate number of hikers who used the trail this summer is 1500 with past visitor attendance as shown in Figure 4.

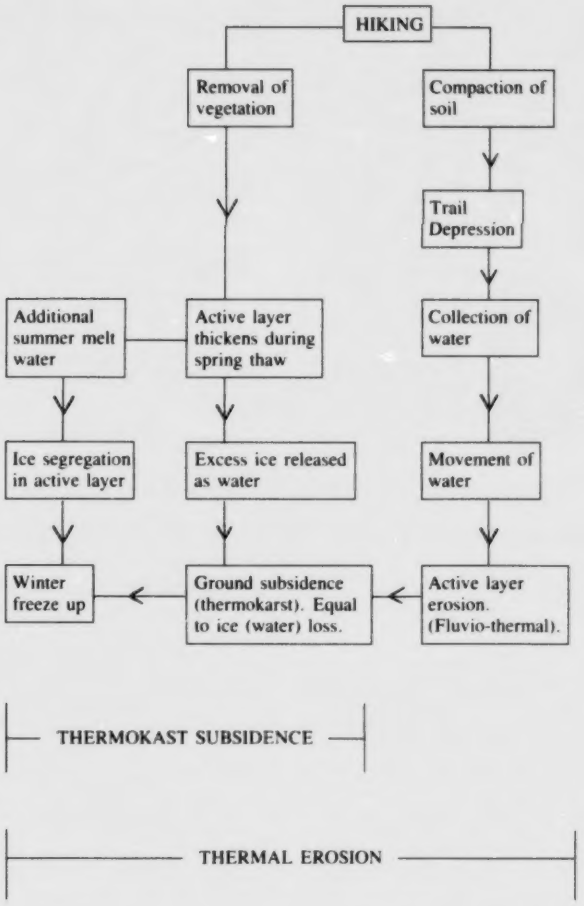


Figure 6. Degradation on terrain containing sub-surface ice. The left hand side of the figure illustrates the processes of thermokarst subsidence, while the whole figure illustrates the processes of thermal erosion.

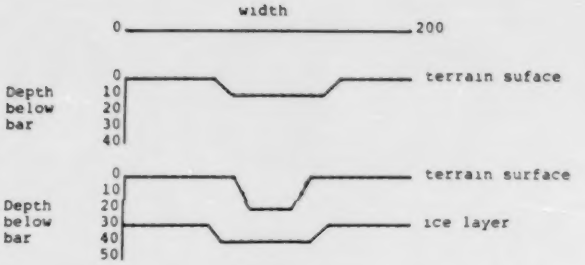


Figure 7. Schematic diagram to illustrate differences in trail 'physical' depressions caused by the existence of sub-surface ice.

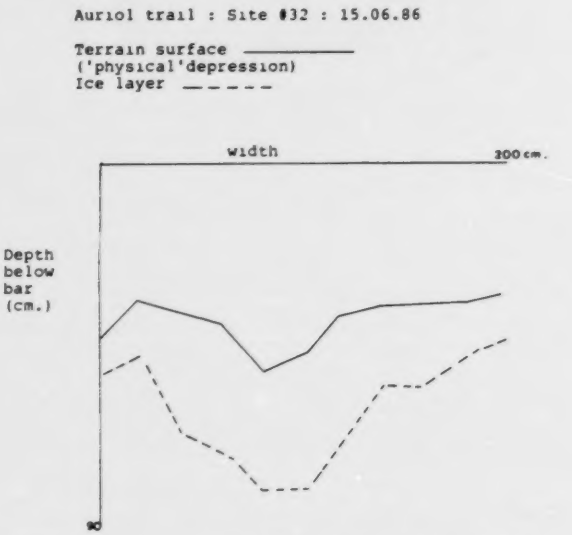


Figure 8. An example of a trail site showing a 'D' shaped 'physical' depression with its underlying ice layer depression.

Data collected

Forty sites were sampled on the Auriol Trail, K.N.P., in early June. Thirty five of those were re-measured in early August. Ninety six sites were measured on the Chilkoot Trail, C.T.N.H.P., in July. At the time of writing this paper, most of the data had not been comprehensively analyzed. However, a number of results and indications of future developments have become apparent from 'eye-balling' the plotted trail depressions and from comparison of photographs taken at each site. The results presented are from the Auriol trail, K.N.P. but give an indication of the approach which will be taken on the Chilkoot trail.

Preliminary results and discussion

The Auriol trail is contained within woodland for the majority of its course. At its eastern end, the trail is at its highest altitude and enters the alpine vegetation zone. Here it follows a former glacial spillway channel where the vegetation is predominantly grass with limited shrub growth (less than one metre in height). The condition of the trail in this particular section is discussed here because of its distinctive landscape contrast, and because this was the only area where sub-surface ice was discovered. The presence of ice introduces an aspect of trail management which is special to northern Parks.

It was anticipated that an important controlling terrain factor would be the existence of permafrost, whether sporadic, discontinuous or continuous. This would generate thermokarst subsidence if the surface-insulating vegetation was removed or degraded in any way (see French 1976 for definitions). This would result in permafrost degradation and downwearing of the trail (Mackay 1970). The mechanics of this process are illustrated in Figure 6, where the active layer has produced positive feedback.

If this process was occurring, then the trail condition would be characterized by a 'U' shaped 'physical' depression and, as a result of the active layer thickening, a depression in the sub-surface ice layer. e.g. Figure 7.

In the section of the Auriol trail under study, 5 sites were found to contain sub-surface ice in July. Three of these had physical and ice layer depressions (e.g. Figure 8 and Plate 1), with the other two sites having either an ice layer or a physical depression. In August, nine sites were sam-

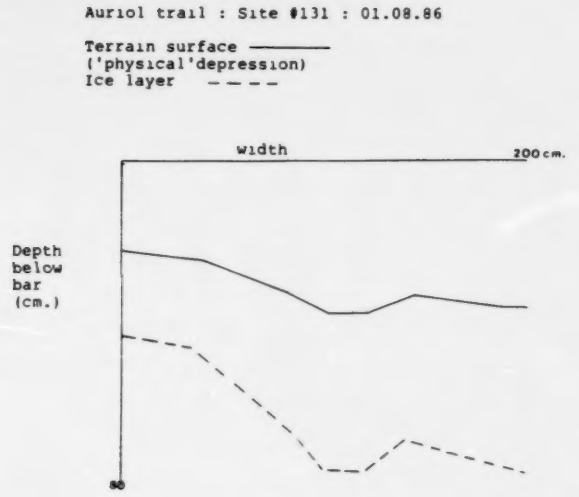


Figure 9. An example of an ice layer depression without the 'U' shaped trail 'physical' depression.

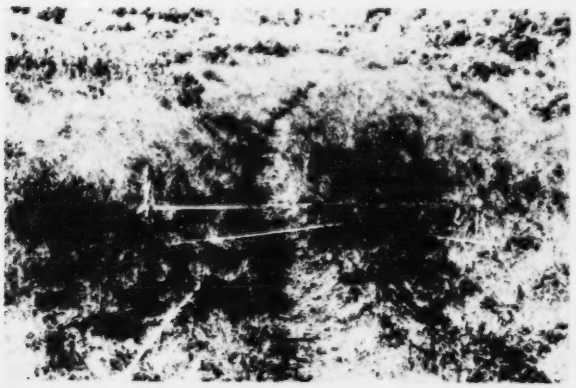


Plate 1. An example of the greater 'U' shaped 'physical' depression found in areas of the Auriol Trail which contain sub-surface ice.

pled in the glacial spillway, three of which had ice layer depressions. However these sites do not have the typical 'U' shaped depression (see Figure 9 and Plate 2). This was only found at two sites and their ice-layer fell on one side of the trail but did not rise on the other side (see Figure 10 and Plate 3). Clearly only some of the data fit the thermokarst theory. At this point in the analysis other factors, for example soil texture, slope and aspect, have not been introduced and so it is not possible to accept that the ice layer is the key controlling variable of trail condition in this section of the trail. Alternatively the idea of thermokarst may be too simple. The trail depressions are significantly greater (see, for example Plate 3) in this section of the trail and possibly additional thermal processes (see French 1976) are operating. Although backwearing would appear to be minimal (as indicated by the steep depression sides), it must not be overlooked that thermal erosion may be acting in harmony with thermokarst subsidence, the characteristics of which, flowing water, a slope and ice, were present (e.g. Plate. 4), especially in early June when snow melt was still occurring. The

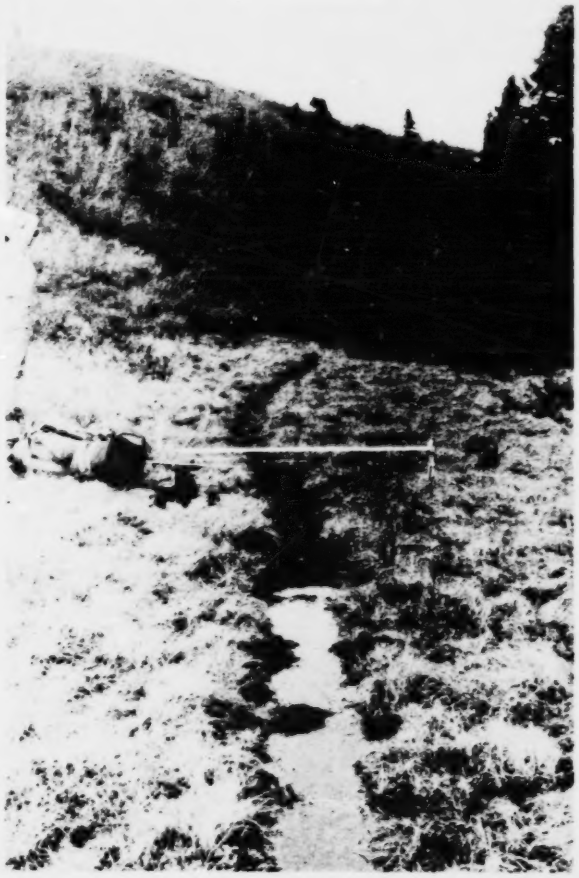


Plate 2. Auriol Trail, site #131, illustrating that the existence of an underlying ice layer depression does not always produce a 'U' shaped trail depression.

processes are shown in Figure 6. Also thermal processes should not be focused upon to the exclusion of other processes.

Management implications

Through quantification of the data, generalizations can be made about hiking-induced degradation of the trail. These can then be used as foundations for wilderness management. Even though it is too early in the execution of this study to state that sub-surface ice is an important control of trail condition and produces terrain sensitive to trail degradation, it is useful for this paper to assume this because it gives an insight into the applications of this type of work.

Three possible management problems and scenarios are:

1) Areas containing sub-surface ice should be avoided when designing and locating trails because this may result in over-deepening and consequent aesthetic impact. Possible solutions could be either a) Re-location, b) Trail maintenance or c) Un-marked trails.

a) *Re-location* may solve the problem but it may also result in avoiding the wilderness areas desired by the hikers. For example, in K.N.P. if trails were restricted to non

Plate 3. Auriol Trail, site #127, illustrating a 'U' shaped depression where the ice layer falls at one side of the trail and does not rise at the other.

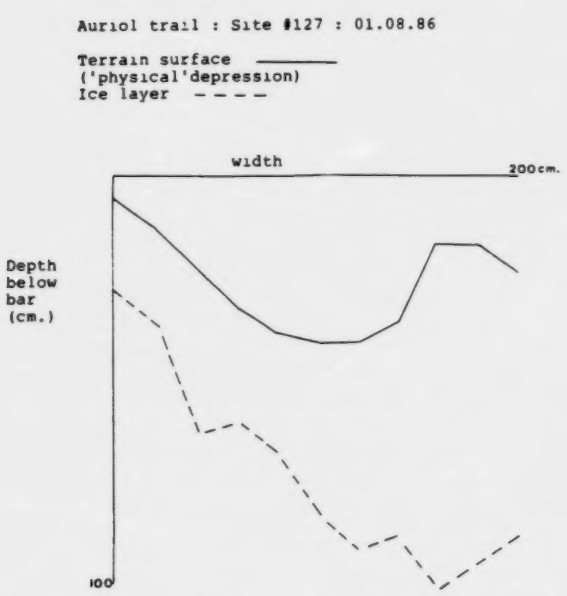


Figure 10. An example of a 'U' shaped trail depression without the complete ice layer depression.

ice areas, then hikers would be contained within the lowland forest and would not have the opportunity of viewing the spectacular vistas from above the tree line.

b) *Trail maintenance* is a costly solution to trail management (Garland 1985), and reduces the wilderness quality of the trail area. There is also the doubt whether the maintenance would work. For example on the Chilkoot trail, some of the water-logged sections have been planked to prevent further erosion. These planks tend to be difficult to walk on and so the hikers have developed their own trail to the side of the planks. This is illlustrated in Plate 5.

c) *Unmarked trails* encourage dispersion of hikers in the hope of preventing impact. The extreme case of this is practiced in Denali National Park, Alaska where hikers gain permits for access to particular zones of the park. Within these zones there are no recognised departure or destination points. This approach appears to be working, although

Plate 4. The existence of flowing water, a slope and subsurface ice can generate thermal erosion which further degrades the trail condition.

Plate 5. An example of trail maintenance causing further trail degradation on the Chilkoot Trail.

trails are in evidence at some natural points of concentration such as stream crossing points and ridges. In K.N.P. there are designated 'routes' in some areas rather than official trails. The idea again is to encourage dispersion. The Kaskawulsh West is one of these routes but does not contain sub-surface ice. However, because hikers

Plate 6. Trail development at points of natural concentration in the Slims River West of Kluane National Park; an area of unmarked trails.

depart from the same point (Bullion Creek), and are heading towards the same destination (Observation Mountain), they tend to follow the same route. This has resulted in significant trail development at points of concentration, see, for example Plate 6. Although the dynamic geomorphological features of this area (e.g. flood plains) are removing many of the trails, this illustrates how uncontrolled dispersion may not solve the problem of deteriorating trail conditions. This approach may be unsuitable for areas with sub-surface ice. To further illustrate this, uncontrolled access on Observation Mountain, K.N.P. (where permafrost exists along with steep slopes), has created a number of trails. These are not prominent at the moment, but may degrade significantly if the number of hikers continues to increase (Parks Canada 1986) and because of the uncontrolled 'route', impact will be widespread rather than confined to one particular trail.

2) Once trail condition has been established the next stage in management is determining whether this is 'unacceptable'. This study allows ranking of degradation in relation to terrain type but does not have a level or rate which is unacceptable. It may be possible to develop an index of unacceptability, which will quantify all trail conditions, but inevitably the key decision is that of the environmental manager. In this case the results of this study may only be applicable to future trail location and design.

3) If thermokarst processes are determined to be significant in developing trail condition, then it is safe to assume that they are most active at certain times of the year. This would favour regulating use at these critical times. For example on the Auriol trail the critical time is during snowmelt when ice is near the surface. The melt water would accelerate the thermokarst problem by using the trails as drainage channels.

These implications for management are only initial ideas but hopefully they give an indication of the types of problems this study will address. The study is a 'first of its kind' in the two Parks and although the data are based on two unique environments, hopefully the results will be applicable to other trail areas in the north.

Acknowledgments

I would like to thank the following for their help, encouragement and financial support in the undertaking of this research: Peter Adams, Trent University, Ont.; Canadian Commonwealth Scholarship Committee; Department of Geography, Trent University, Ont.; Christine Hedgecock, Parks Canada, Whitehorse, Y.T.; Natural Sciences and Engineering Research Council of Canada; Northern Scientific Training Program (D.I.N.A.); Alyson Park, Trent University, Ont.; Parks Canada, Haines Junction, Y.T.; David Welch, Parks Canada, Hull, P.Q.

References

Bayfield, N. G. 1973. Use and determination of some Scottish hill paths. Journal of Applied Research Ecology. Vol. 10. pp 635–644.

Cole, D. N. 1983. Assessing and monitoring backcountry trail conditions, U.S. Dept. of Agriculture, Research Paper. INT-303. pp 71–78.

Coleman, R. 1981. Footpath erosion in the English Lake District. Applied Geography, Vol. 1, pp 121–131.

French, H. M. 1976. The Periglacial Environment. Longmans, London, pp 105–133.

Garland, G. G., Hudson, C. and Blackshaw, J. 1985. An approach to the study of path erosion in the Natal Drakensberg, a mountain wilderness area. Environmental Conservation, Vol. 12, No. 4, pp 337–342.

Jubbenville, A. J. 1978. Outdoor Recreation Management. Saunders, Philadelphia. pp 259–260.

Liddle, M. J. 1975. A selective review of the ecological effects of human trampling on natural ecosystems. Biological Conservation. Vol. 7, pp 17–36.

Mackay, J. R. 1970. Disturbances to the tundra and forest tundra environment of western Arctic. Canadian Geotechnical Journal, Vol. 7, pp 420–432.

McNamee, K. A. 1986. Canadian wilderness–what future? Park News, Vol. 22, No. 2, pp 41.

Parks Canada. 1980. Kluane National Park Management Plan. Hull, P.Q.

Parks Canada. 1984. Kluane National Park Conservation Plan. pp 86–88 and p B2. Hull, P.Q.

Parks Canada. 1985a. Northwest Territories Caucus Report. Heritage for Tomorrow, Canadian Assembly on National Parks and Protected Areas. 26p. Hull, P.Q.

Parks Canada. 1985b. Auriol trail addition. Kluane National Park screening report. 4p. Haines Junction, Y.T.

Parks Canada. 1986. Proposed Chilkoot Trail National Historic Park. Management Planning Program. No. 1. Whitehorse, Y.T.

Parsons, D. J. 1980. Measuring Impacts of Wilderness Use. Parks, Vol. 5, No. 1, pp 8–12.

Wall, G. and Wright, C. 1977. The Environmental Impact of Outdoor Recreation. Dept. Geography Publications. Series 2, University of Waterloo.

Welch, D. M., and Churchill, J. 1985. Hiking trail conditions in Pangnirtung Pass, Baffin Island, Canada. Parks Canada and Trent University. 19p

TEMPORAL ASPECTS OF THE DISTRIBUTION, ABUNDANCE AND BEHAVIOUR OF BELUGA WHALES (*DELPHINAPTERUS LEUCAS*) IN THE CHURCHILL HARBOUR

P.D. Idle, P.D. Watts, and F.F. Mallory

Department of Biology, Laurentian University, Sudbury, Ontario P3E 2C6

and

The Institute of Arctic Ecophysiology, Churchill, Manitoba R0B 0E0

Level: P.D. Idle, Master's

Abstract

Beluga whales (*Delphinapterus leucas*) congregate in estuaries at selected locations in the Canadian Arctic, during the summer months (Fraker *et al.*, 1979). Observations of these whales have indicated that the beluga distribution is influenced by tidal action (Doan, 1948; Douglas, 1951), but systematic studies had not been conducted between tidal points throughout a summer or during consecutive summers. Beluga whales were studied in the Churchill River estuary in Churchill, Manitoba, Canada (lat. 58°47′N, long. 94°12′W), from 1982 to 1986. Distribution, abundance and behaviour were examined by conducting hourly counts from one peak tide to the next for the months of July and August. The number of adult and immature whales and females with young moving into and out of the estuary was recorded. Behaviour was recorded as to whether the whales were travelling, shallow diving, deep diving or stationary. Whales were further classified according to association as singles or in groups. Whale activity and behaviour were subsequently correlated with season, time of day, weather, human disturbance, tidal changes, annual changes, water and ice conditions, and spatial distribution and location. Whales were more abundant at the mouth of the estuary at low tide. Three types of possible feeding behaviours were observed. The birth of a calf approximately 1 m in length was witnessed. Cooperative feeding behaviour was seen in 1986. Human disturbances in the form of port activities, boat traffic and hunting may affect whale behaviour.

Key words: Beluga, *Delphinapterus*, behaviour, feeding, birth.

Résumé

Les bélougas (*Delphinapterus leucas*), se rassemblent au cours de l'été dans les estuaires de plusieurs fleuves arctiques (Fraker & coll., 1979). L'observation de ces baleines a montré que leur répartition est influencée par les courants de marée (Doan, 1948; Douglas, 1951), mais on n'a pas mené d'études systématiques entre ces rassemblements, au cours de l'été ou pendant des étés consécutifs. Les auteurs ont étudié le comportement des bélougas dans l'estuaire du fleuve Churchill, à Churchill, Manitoba (58°47′ de lat. nord, 94°12′ de long. ouest) entre 1982 et 1986. Ils ont évalué leur répartition, leur nombre et leur comportement grâce à des comptages horaires d'une haute marée à l'autre, en juillet et août, et ils ont noté le nombre des bélougas adultes et immatures, des femelles et des jeunes entrant et sortant de l'estuaire, ainsi que leur comportement: déplacements, plongée peu profonde, plongée profonde et mouvements sur place. Ils ont aussi classé ces bélougas en animaux isolés ou groupés. Ultérieurement, les auteurs ont corrélé ces activités et comportements des bélugas avec la saison, l'heure, le temps, la présence humaine, les mouvements de la marée, les changements annuels, l'état des glaces et des eaux, la répartition des bélougas dans les eaux et le lieu. Ils ont observé trois genres de comportements lors de leur alimentation, ainsi que la naissance d'un baleineau long de 1 m. En 1986, les baleines pourchassaient les bancs collectivement. Les activités humaines: trafic portuaire, circulation de bateaux et chasse pourraient affecter le comportement des bélougas.

Mots-clés: Bélouga, *Delphinapterus*, alimentation, naissance.

Introduction

The distribution of the beluga (*Delphinapterus leucas*) is restricted to the Northern Hemisphere and mainly to the arctic and subarctic regions. It was not until the end of the 1920's and early 1930's, that interest was shown in the ecology of the beluga (Kleinenberg *et al.*, 1964). To date, some populations of beluga whale have been depleted. The population living in the St. Lawrence River, which numbered several thousand in the past (Pippard and Malcolm, 1978) has been estimated at less than 350 whales. In several locations in the Arctic, high concentrations of beluga whales still congregate in estuaries, during the summer months (Fraker *et al.*, 1979). Doan (1948) postulated that whales enter estuaries on the flood tide and leave the river on the ebb. These areas of concentration have been thought to be calving grounds (Sergeant, 1973). Fraker (1977) hypothesized that white whales congregate in estuaries primarily for the thermal advantage to all age classes, especially newborn calves. However Finley (1976), reported in Finley *et al.* (1982), observed neonates offshore, in the eastern arctic, preceding the arrival of whales at estuaries and concluded that the concentration areas may not be critical to successful calving. Finley *et al.* (1982) subsequently suggested that the beluga enter these warm, shallow waters to moult. Sergeant (1973) postulated that feeding is not occurring in these areas of concentration, as most of the whales sampled had empty stomachs. Fraker (1977) observed whales orienting themselves into the wind and suggested that high wind speeds may also affect whale behaviour.

The objective of this study was to determine whether the abundance, distribution, behaviour and age structure of populations of beluga vary with tide, season, year, human disturbance, and water and ice conditions in the Churchill River estuary, Churchill, Manitoba, Canada.

Materials and methods

Beluga whales (*Delphinapterus leucas*) were studied in the Churchill River estuary in Churchill Manitoba, Canada (lat. 58°47′N, long. 94°12′W), from 1982 to 1986.

Age composition, distribution, abundance and behaviour of the beluga were examined via land-based observations. Observations were conducted each hour in three stages. A scan of the study area, lasting approximately five minutes, was conducted to determine distribution and abundance. A second five minute scan was conducted to discern whale behaviour and group structures. Finally, age structure, immigration to and emigration from, the study area was examined for a 15 minute period. Counts were conducted seven hours/day, six days a week for the months of July and August from 1982 to 1985 and four days a week during 1986. Land-based counts and observations were conducted from two vantage points — the port of Churchill, and Cape Merry (Fig. 1). Whale activity in the harbour was monitored from the Harbour's Board Gallery which rises approximately 30 meters above the water. Whale activity at the mouth of the Churchill River was observed from atop the cannon battery at Cape Merry, a part of the historic Fort Prince of Wales fortifications (Fig. 1).

Observations using 7 × 35 binoculars were started at the peak tide closest to 0900 hours Central Daylight Saving Time each study day. This was done to reduce glare which impaired counts and to obtain data on morning and afternoon whale activity patterns.

The times of counts between the two locations were synchronized. Scans from both locations began along the intersection of grids DC-DD and EC-ED (Fig. 1). The observer situated at Cape Merry was responsible for scanning the seven grids BD to DE, while the observer at the Gallery was responsible for scanning the ten grids EC to HE (Fig. 1). The number and position of the whales in each grid were recorded.

These scans were repeated and the behaviour of each whale was recorded. Travelling was defined as a constant forward movement with the whale submerging and surfacing in a 3–6 second cycle. Shallow diving was characterized by a broken movement in any direction, with a low arch to the back at the beginning of the dive and submerging for 8–12 seconds. Deep diving was defined as a high arch of the back prior to the dive with the whale remaining submerged for an extended period or often disappearing completely. Tail flukes sometimes broke the surface of the water prior to a deep dive, but usually not during shallow diving. A whale was classified as stationary if it remained motionless at the surface for more than 30 seconds. Whales were further classified according to association as singles or as groups. A group was defined as three or more whales in close proximity. The number of whales in each group was recorded.

In addition, the observer at Cape Merry watched along the DC-DD grid for another 15 minute period, recording the number of adult and immature whales, and adults with young moving into and out of the estuary. Large, white whales were designated as adults and light to dark grey whales as immatures. Calves were approximately one-third of the adult length, dark gray to dark blue or brown in colour, in close

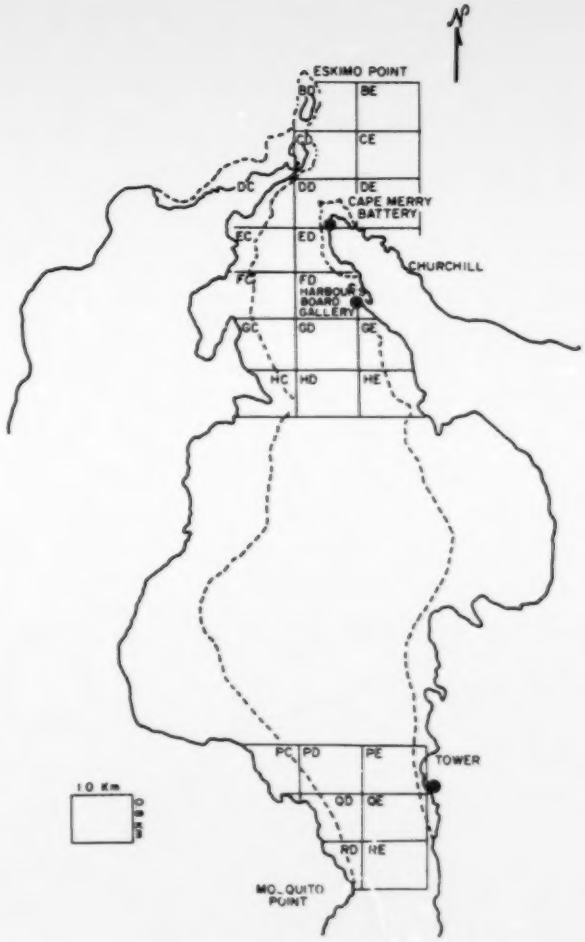


Figure 1. Map of the Churchill River estuary. The dots represent the three vantage points: Cape Merry Battery, Harbour's Board Gallery and the tower. The dotted line refers to the low tide mark.

proximity to, and surfacing in synchrony with a large, white adult.

Whale activity and behaviour were subsequently correlated with season, time of day, water condition, human disturbance and tidal changes. Boat and port activities were recorded. Water condition with no whitecaps, was rated "zero"; with one to five percent whitecaps, "one"; and five percent or more whitecaps, "two".

In 1986, a third vantage point was selected and an eight metre high tower was constructed on the east side of the river, approximately six km from the river mouth. The seven grids PC to RE were monitored (Fig. 1). Since much of this area consisted of tidal flats during low tide, observations began two hours before high tide and continued to two hours after high tide. These counts were synchronized with counts conducted from the other two observation sites. As at Cape Merry, the number of adults, immatures and female whales with calves moving into and out of two grids, PC and PE, were recorded. Counts occurred four days a week for the months of July and August in 1986.

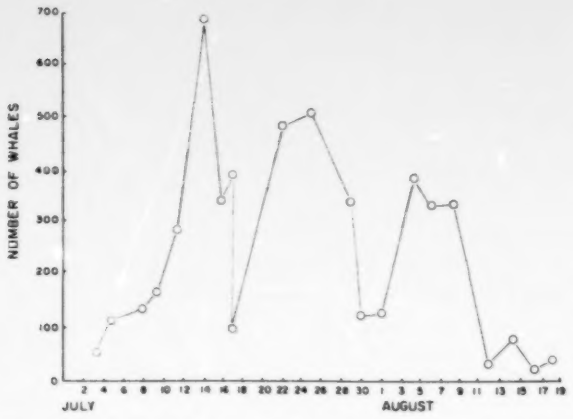


Figure 2. Number of whales/day observed during the seven hourly scans each day during July and August, 1986.

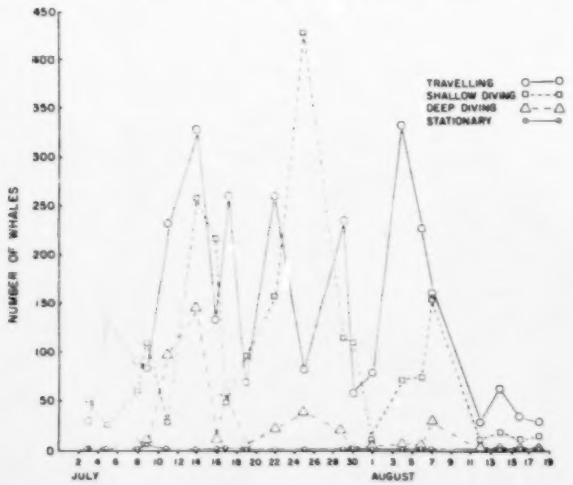


Figure 3. Number of whales travelling, shallow diving, deep diving and stationary for the seven, hourly scans each day during July and August, 1986.

Results

Preliminary investigations of the data from the two vantage points at the north end of the estuary in 1986, show that whale numbers were low at the beginning of July and increased to a maximum of 673 during the seven hourly scans of July 14 (Fig. 2). Numbers remained high during the remainder of July and the beginning of August except for July 19, July 30 and August 1. After August 7, numbers gradually declined (Fig. 2).

Figure 3 shows the number of whales travelling, shallow diving, deep diving and stationary per day in 1986. With the exception of stationary behaviour, which was rare in this part of the estuary, the frequency of whales exhibiting each behaviour, increased as whale numbers increased. On most occasions, travelling was the most common behaviour observed. However, on July 25, 1986, the frequency of whales shallow diving was considerably higher than that of the other three behaviours (Fig. 3). On that day 432 whales were observed shallow diving during the seven hourly observation periods.

The numbers of adult and immature whales observed per day

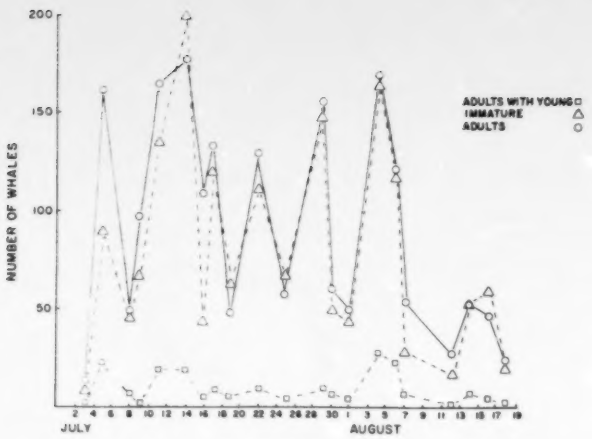


Figure 4. Total number of adult, immature, and adults with young observed during the seven, hourly observation periods during July and August, 1986.

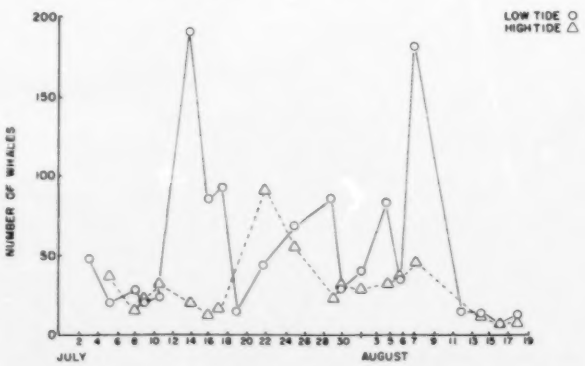


Figure 5. Number of whales observed each day at high and low tide at the harbour and mouth of the estuary during the months of July and August, 1986.

were very similar (Fig. 4). At the harbour and mouth of the estuary, adults with young were less often observed than the other two age classes, but the fluctuations in their numbers follow those of adult and immature whales (Fig. 4).

Figure 5 shows the number of whales observed during the low tide scan in comparison with whale numbers at high tide. For most days at the harbour and mouth of the estuary, more whales were observed at low tide than at high tide. An exception to this occurred on July 22 when more whales were observed at high tide. The highest numbers of whales observed were at the low tides of July 14 and August 7.

Discussion

At Cunningham Inlet, northern Somerset Island, beluga arrive about July 15 and leave about August 20 (Bruemmer, 1986). Finley *et al.* (1982) observed beluga arriving at Creswell Bay, Somerset Island, on July 21 and departing on August 16. Fraker *et al.* (1979) described a pattern of early peaking of numbers, followed by a moderate decline and relative stability to the end of July for the beluga in the Mackenzie River estuary. The first whales entered the Churchill River about mid-June in 1986. Their numbers were low at the beginning of the season and remained low until about July 9, after which they increased (Fig. 2). When high

winds made the estuary rough on July 19 the number of whales there decreased. Numbers at the harbour and mouth of the estuary were low on July 30 and August 1 when the whales remained further upriver. After August 7, a series of gales occurred and whale numbers decreased and never recovered.

Shallow diving may be associated with feeding. Fraker *et al.* (1979) described a possible feeding behaviour where whales were diving while Glaucous Gulls (*Laurus hyperboreus*) were present. In this study, Arctic Terns (*Stoma paradisaea*) and Bonaparte Gulls (*Larus philadelphia*) were seen diving amongst groups of shallow diving whales on many occasions during the summer of 1986, when schools of capelin (*Mallotus villosus*) were observed in the estuary. On these days, evidence of cooperative feeding behaviour was observed. Groups of whales oriented themselves in circles and individual whales dove into the center of the ring. The whales were swimming fast and shallow diving with very quick breaths at the surface. At low tide on July 22, whales were observed forming a half-circle just off the steep, rocky shore, just beyond the grid DE near Cape Merry (Fig. 1). Individual whales swam towards the rocks and were seen to have capelin in their mouths.

Deep diving may be a means of travelling, fleeing or feeding. Fraker *et al.* (1979) described a feeding behaviour where whales were observed deep diving in the absence of gulls. Two types of deep diving in the absence of gulls were observed in the Churchill estuary. The first was characterized by groups of whales deep diving with a frenzy of activity. The whales broke the surface very quickly, with much splashing, and rose high out of the water, almost breaching. This may represent predation on transient schools of fish at depth. On July 3, this behaviour occurred in an area where a fisherman was catching whitefish (*Coregonus sp.*). The second type of behaviour was characterized by groups of whales deep diving in a small area, but seemingly at a much more relaxed pace. The whales broke the surface without any splashing and remained at the surface for longer periods before deep diving. This may represent bottom feeding on crustaceans.

These apparent feeding behaviours in the harbour and mouth of the estuary occurred most often at low tide, but, on July 22, much shallow diving behaviour and gull activity occurred at high tide. Feeding may be correlated with the movements of fish which may only partially be influenced by tidal action.

High numbers of whales were also observed at the low tide of August 7 when a whale hunt was being conducted upriver and a mixed group of 153 adults, immatures and females with young was observed in front of the Harbour's Board Gallery (Fig. 1). At this time 23 calves were counted and one female was observed giving birth to a tan coloured calf, approximately 1 m in length. At Creswell Bay, Somerset Island, in 1975, Finley *et al.* (1982) observed that from July 21 to August 16, the proportion of newborn calves increased from four percent to twelve percent of the herds, although they did not observe any birthing activity. Figure 4 suggests that the proportion of calves remained constant throughout the season.

Finley *et al.* (1982) also described belugas panicking and fleeing from the Cunningham river mouth on northern Somerset Island as their aircraft passed overhead. In the Churchill estuary, this behaviour was observed when whale hunts were being conducted and when airboats were running on the river. During the summer of 1986, when pile driving was being conducted in front of the Harbour's Board Gallery, the whales were noticeably absent from the estuary. In conclusion, the data suggest that tidal action, season, water conditions, prey availability and human disturbance may all influence beluga abundance and behaviour.

Acknowledgments

I wish to thank the board members and staff of the Institute of Arctic Ecophysiology and especially Barb Draper and Steve Hansen for their technical assistance. Special thanks goes to Ports Canada, Churchill and Parks Canada, Churchill for use of their facilities. I would like to thank Pat Dwyer for helpful comments on earlier drafts of this paper and Chris Blomme for graphics. From 1982 to 1984, this project was supported by the World Wildlife Fund of Canada.

References

Bruemmer, F. 1986. White whales on holiday, Natural History 1:41–48.

Doan, K.H. 1948. Beluga of the Churchill region at Hudson Bay, Bulletin of the Fisheries Research Board, No. 98. 27p.

Douglas, C.W. 1951. Report on beluga investigations at Churchill in 1950. Fisheries Research Board of Canada MS Report Biological Station 485: 33p.

Finley, K.J., Miller, G.W., Allard M., Davis, R.A. and Evans, C.R. 1982. The beluga (*Delphinapterus leucas*) of northern Quebec: distribution, abundance, stock identity, catch history and management. Canadian Fisheries and Aquatic Science Technical Report 1123.

Fraker, M.A. 1977. The 1976 white whale monitoring program Mackenzie River Estuary, N.W.T. Prepared for Imperial Oil Limited, Calgary, by F.F. Slaney and Company Limited, Vancouver, B.C. 73p.

Fraker, M.A., Gordon, C.D., McDonald, J.W., Ford, J.K.B., and Cambers, G. 1979. White whale (*Delphinapterus leucas*) distribution and abundance and the physical and chemical characteristics of the Mackenzie Estuary. Fisheries and Marine Services Technical Report No. 863. 56p.

Kleinenberg, S.E., Yablokov, A.V., Belkovitch, B.M., and Tarasevich, M.N. 1964. Beluga (*Delphinapterus leucas*): Investigation of the species. Israel Program for Scientific Translations, Jerusalem. 376p.

Pippard, L., and Malcolm, H. 1978. White whales: Observations on their distribution, population and critical habitats in the St. Lawrence and Saguenay River. Department of Indian and Northern Affairs, Parks Canada Project C1632, Contract 76-190, [vii] + 161p.

Sergeant, D.E. 1973. Biology of white whales (*Delphinapterus leucas*) in western Hudson Bay. Journal of the Fisheries Research Board of Canada 30: 1065–1090.

THE RESPONSES OF SEDGE COMMUNITIES TO HERBIVORY, LA PÉROUSE BAY, MANITOBA

Peter Kotanen

Department of Botany, University of Toronto, Toronto, Ontario M5S 1A1

Level: Master's

Abstract

The responses of sedges to herbivory have been investigated at La Pérouse Bay, Manitoba, where there is a colony of approximately 7000 pairs of geese. In the early spring the geese feed intensively on the basal portions of shoots of the freshwater sedges, *Carex aquatilis* and *Carex* × *flavicans*. They discard the remainder of the shoots. By the time the goslings hatch in late June, foraging has shifted to the clipping of leaves of the salt-marsh sedge, *C. subspathacea*, although leaves of *C.* × *flavicans* are also clipped. Both species show a growth response to moderate defoliation. Regrowth of clipped leaves, production of new leaves and a fast turnover of leaves characterize the response. The soluble nitrogen in faeces of the geese appears to be necessary to maintain the growth.

The foraging in early spring has resulted in local damage to freshwater sedge communities at La Pérouse Bay, and extensive destruction of the sedge communities at the McConnell River colony on the west coast of Hudson Bay, where there are about 115 000 pairs of Snow Geese. The results suggest that the stability of these communities is sensitive to the timing of herbivory, the plant organs selected by the geese, and the intensity of foraging.

Key words: Sedges, herbivory, Lesser Snow Geese, west and south Hudson Bay coasts.

Résumé

Les peuplements de plantes herbacées des basses-terres du littoral de la baie d'Hudson sont broutés par les petites oies blanches en migration ou en couvaison.

L'auteur a étudié les conséquences de ce broutage des carex à la baie de La Pérouse, Manitoba, où se trouve une colonie d'environ 7 000 couples de petites oies blanches. Au début du printemps, ces oies broutent intensément les bases des pousses des carex d'eau douce, *Carex aquatilis* et *Carex* × *flavicans*, et rejettent le restant des pousses. Au moment où les oisillons éclosent, à la fin de juin, les oies broutent surtout les feuilles du carex halophyle *C. subspathacea* et aussi celles de *C.* × *flavicans*. Les deux espèces réagissent par un surcroît de développement à une défoliation modérée. La repousse des feuilles broutées, le développement de nouvelles feuilles et un rapide remplacement des feuilles caractérisent les réactions des carex. Le nitrate soluble présent dans les déjections des oies paraît nécessaire au maintien de cette croissance.

Le broutage par les oies au début du printemps a endommagé localement les peuplements de carex de la baie de La Pérouse, mais ils ont été détruits plus largement aux alentours de la rivière McConnell, sur le littoral ouest de la baie d'Hudson, où se trouve une colonie de 115 000 couples d'oies blanches. L'observation indique que la stabilité des peuplements de carex dépend étroitement du moment du broutage, de son intensité et de l'organe végétal consommé.

Mots-clés: carex, broutage, petite oie blanche, littoraux ouest et sud de la baie d'Hudson.

Introduction

Herbivory is a process of ecological and evolutionary importance. Herbivores commonly modify or regulate species richness and evenness, production, energy flow, nutrient flow, spatial distribution, population dynamics, and many other features of plant communities (Harper, 1977; Crawley, 1983). Conversely, the survival of herbivores themselves depends upon the availability of a sufficient supply of suitable food. As a result, any deterioration in food quantity or quality can produce reverberations throughout the ecosystem.

Efforts to produce any coordinated theory of plant-herbivore relations have met with only very limited success. The explanation for this failure lies in the great complexity of the processes involved; multiway interactions and feedback loops abound. This complexity makes generalization across different systems very difficult, but does not prevent analyses of plant-herbivore systems in which the important processes have been identified.

The aim of this paper is to identify and discuss the most important processes determining whether sedge communities persist or collapse under the influence of herbivory by Lesser Snow Geese. In particular, the consequences of food choice, phenology, spatial variation, year-to-year variation, the relative ability of different species to tolerate damage, and the intensity of herbivory will be considered. Only by a detailed analysis of such diverse factors can a useful understanding of plant-herbivore systems be achieved.

Methods

Study sites

Lesser Snow Geese (*Anser caerulescens caerulescens*) nest primarily in a limited number of colonies in coastal areas of the Canadian Central Arctic and Subarctic (Kerbes, 1974). Most of the data discussed in this paper were collected between 1984 and 1986 in a colony at La Pérouse Bay, Manitoba, located on the coast of Hudson Bay about 30 km east of Churchill (Figure 1).

The coastal tundra and salt marshes of La Pérouse Bay support a nesting colony of about 7000 pairs of Snow Geese, which annually raise about 15 000 goslings to fledging. Each spring, the area also briefly supports tens of thousands of migrants; smaller numbers of migrants use the area each fall. Snow Geese are by far the most important local herbivores.

Figure 1. Map of the Hudson Bay region showing the La Pérouse Bay study site and the McConnell River. From Jefferies and Kerbes (1985).

Most of the summer feeding of breeding adults and goslings occurs on the extensive (15 km^2) salt marsh bordering Hudson Bay, close to the primary nesting areas. These flats are dominated by the sedge *Carex subspathacea* Wormsk. and the grass *Puccinellia phryganodes* (Trin.) Scribn. and Merr. (Jefferies *et al.*, 1979; Cargill and Jefferies, 1984b). Significant foraging also occurs in the willow-dominated freshwater areas on the inland edges of the salt marshes. In these areas, the primary forage species are *Carex aquatilis* Wahl. and *Carex* × *flavicans* Nyl., which grow in nearly pure stands in wet areas. All three of these sedges and *Puccinellia* spread vigorously by clonal growth; successful sexual reproduction is probably very rare or lacking at this location.

In the spring, the geese arrive in mid-May during melt, long before significant growth of leaves begins. Most early spring feeding occurs in freshwater areas where geese pull the developing shoots of *C. aquatilis* and *C.* × *flavicans*, consume the swollen bases, and discard the remainder. Some additional feeding also occurs on the salt marshes where geese locally strip exposed vegetation down to the underlying sediment. However, by the time the goslings hatch in late-June, this grubbing has been almost completely replaced with partial defoliation (grazing) of *Puccinellia* and *C. subspathacea* in saltmarsh habitats. This grazing is very intense; the saltmarsh vegetation is uniformly reduced to 2.5 cm or less in height. Some grazing, especially of *C. flavicans*, also occurs locally during the summer in freshwater sedge meadows. A small amount of grubbing and shoot pulling in both freshwater and saltwater habitats resumes in late August during fall migration.

More information on the vegetation of La Pérouse Bay may be found in Jefferies *et al.* (1979), Cargill and Jefferies (1984b) and Bazely and Jefferies (1986).

Study methods

Similar methods have been used for each *Carex* species to allow the investigation of morphological responses to herbivory by geese. The approach has been to compare the demography of leaves and shoots between plants within chickenwire exclosures and plants exposed to natural grazing. The preliminary statistical analyses used here still may be further refined; it is considered unlikely, however, that significant changes in their outcomes will occur.

Further information on the demographic and statistical techniques reported here may be found in Kotanen and Jefferies (1987).

1. Demography of leaves

a. *Carex subspathacea*

The demography of leaves was investigated in six permanent 0.5 × 0.5 m plots established on the saltmarsh in June 1984. Three of these plots were exclosed. Within each plot, 81 shoots were randomly chosen and permanently marked with wire rings to allow reidentification. All leaves on each shoot were marked with distinctive patterns of ink dots to allow the estimation of production and deaths of leaves. Complete samplings were performed about every 15 days until early September; a small number of shoots was successfully located in June 1985, allowing the description of overwinter demography. Statistics are based on the shoots that survived the entire season.

b. *C. flavicans*

In June 1985, six (0.5 × 0.5 m) plots were established in freshwater moss carpet communities frequently visited by the geese; three were exclosed. Within each plot, 25 randomly-chosen shoots were marked and followed, as described above. Sampling was performed every 10 days until the end of August with one final sampling in June 1986.

c. *C. aquatilis*

Since grazing of *C. aquatilis* is very patchy and unpredictable, leaf demography was not investigated in this species.

2. Demography of shoots

a. *Carex subspathacea*

In June 1985, six (0.5 × 0.5 m) plots were established on the salt marsh; three were exclosed. One unexclosed plot was later abandoned because of silt deposition. Within each plot, three (2 × 2 cm) subplots were randomly chosen and delimited with wire perimeters. All shoots in each subplot were marked with adjacent toothpicks and followed until June 1986. In May 1986, an additional six pairs of plots were established in order to increase sample size and to reduce bias from early spring grubbing. In each of these plots, all shoots in five (2.5 × 2.5 cm) wire-delimited subplots were marked and followed as described above.

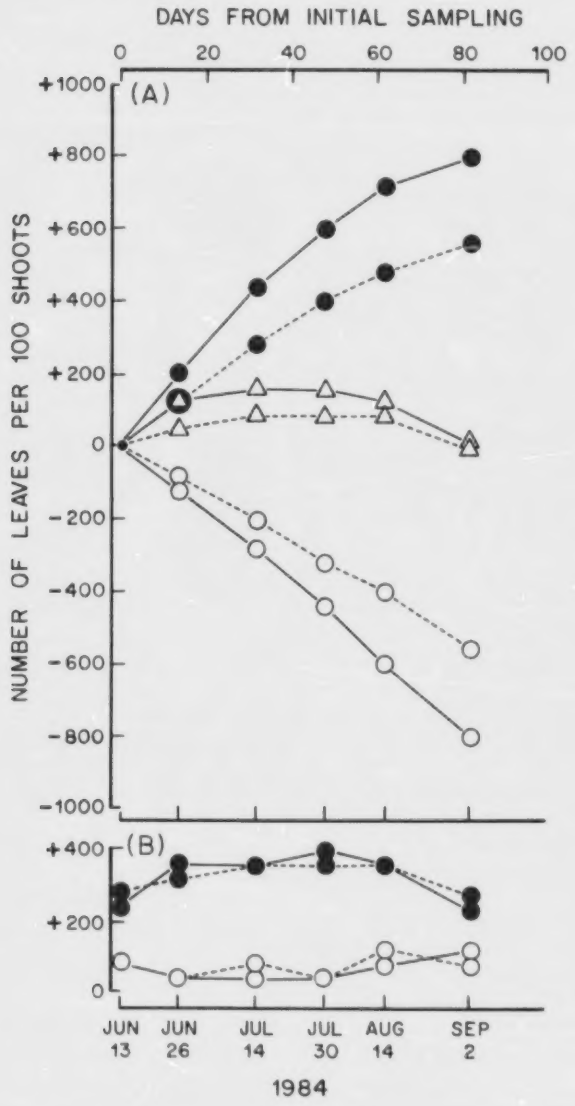


Figure 2. Changes in numbers of leaves of grazed (solid lines) and ungrazed (broken lines) plants of *Carex subspathacea* at La Pérouse Bay, Manitoba from June to September 1984. (A) Cumulative births (●), cumulative deaths (○), including deaths of leaves produced before 11 June 1984, and change (births minus deaths) in number of live leaves (△). (B) Standing numbers of live leaves, which includes, if applicable, those produced before 11 June 1984 (●), and standing number of dead leaves, including leaves which died before 11 June 1984, if applicable (○). Modified from Kotanen and Jefferies (1987).

b. *C.* × *flavicans*

In June 1985, all shoots within a 15 × 15 cm subplot within each leaf demography plot were ringed with wire and followed until June 1986. In June 1986, five new pairs of plots were established before heavy pulling of shoots occurred; all shoots in 10 (5 × 5 cm) wire-delimited subplots in each of these plots were ringed and followed.

c. *C. aquatilis*

Twelve 25 × 25 cm plots were established in June 1986 before heavy shoot pulling occurred. Each plot was delimited and divided into four equal quadrants with wire (half were exclosed). All shoots in each quadrant were ringed with wire and followed through the season.

Results

1. Demography of leaves

a. *Carex subspathacea*

Between 11 June and 3 September 1984, grazed shoots of *C. subspathacea* produced an average of 8.2 leaves, significantly exceeding the average of 5.7 produced per exclosed shoot ($F_{1,4} = 27.42^{**}$, nested ANOVA; Figure 2). Production between 3 September 1984 and 16 June 1986 added an average of 0.31 leaves to grazed shoots and 0.76 to ungrazed shoots. Although this difference was significant ($p < 0.05$, Kruskal-Wallace test), the small values indicate that production between June and September is by far the most important component of annual leaf production.

Because neither standing numbers of live leaves nor death rates of leaves varied consistently over the summer, it was felt reasonable to assume a stationary population of leaves (Pielou, 1969) and to pool different cohorts of leaves in order to produce within-season survivorship estimates, using the survival routine of SPSSX (Anon., 1986). Although, strictly speaking, life expectancies could not be estimated if any leaves survived the entire sampling period (Berkson and Gage, 1950), the fact that less than 0.2% of all leaves fall into this category suggests that this is a very minor source of bias in this case.

Both grazed and ungrazed leaves on shoots in pooled grazed plots had life expenctancies of about 34 days, as opposed to life expectancies of about 46 days for leaves in pooled exclosed plots. This difference was significant (Lee-Desu $D = 251.4^{***}$; see Anon, 1986).

About 50% of the leaves produced in 1984 in unexclosed plots were grazed by geese before their deaths or before the final sampling in September. Because the geese leave the area in mid-August, it is unlikely significant grazing occurred after the final sampling date.

A much more extensive analysis of these data may be found in Kotanen and Jefferies (1987).

b. *Carex* × *flavicans*

Between 14 June and 31 August 1985, shoots in grazed plots produced an average of 6.0 leaves, compared with an average of 4.1 in exclosed plots. This difference was significant ($F_{1,4} = 8.50^{*}$, nested ANOVA). Substantial production occurred between 31 August 1985 and 17 June 1986, amounting to 1.58 leaves per grazed shoot and 2.25 leaves per ungrazed shoot. This difference was not significant ($t_{86} = 1.18$).

Leaves were long-lived; about 65% of leaves produced after the first sampling date survived past the termination of sampling in August, implying a mean lifespan greater than one year. A significantly greater proportion of those leaves produced in 1985 by ungrazed shoots survived the entire

TABLE 1
Proportions of all shoots in experimental plots which were produced during each sampling period (summer or winter)

Species	Parameter	Treatment	n	Proportion	G
C. subspathacea	summer births	grazed	60	0.13	0.39ns
"		ungrazed	141	0.17	
"	winter births	grazed	34	0.21	3.09ns
"		ungrazed	35	0.06	
C. X flavicans	summer births	grazed	122	0.43	0.99ns
"		ungrazed	152	0.37	
"	winter births	grazed	69	0.25	0.27ns
"		ungrazed	122	0.21	

Data are pooled for plots subjected to the same grazing treatment.

Proportions are compared with adjusted G-tests for independence (Sokal and Rohlf, 1981). See text for details.

season than of those produced by grazed shoots (G_{1df} = 11.71***). Thus, it is likely that leaves of grazed shoots have a shorter mean lifespan than those of ungrazed shoots.

Overall, about 76% of leaves produced in 1985 in grazed plots were clipped by geese before their deaths or before the final sampling.

2. Demography of shoots

a. *Carex subspathacea*

When expressed as (shoots produced)/(shoots initially present plus shoots produced), cumulative production of shoots between 16 June and 1 September 1985 did not differ significantly between grazed and ungrazed treatments (Table 1).

Between September 1985 and June 1986, one ungrazed plot was lost. When expressed as (shoots produced during the winter)/(total shoots observed in June 1986), overwinter production did not differ significantly between treatments (Table 1).

Between 25 May 1985 and 24 August 1985, mean cumulative production of shoots per 2.5 × 2.5 cm subplot totalled 9.47 in grazed plots and 9.03 in ungrazed plots. These values were not significantly different (t_{58} = 0.297).

b. *Carex* × *flavicans*

Most of the pulling of shoots of *C.* × *flavicans* by geese occurs during spring melt. In 1986, about 56.6 ± 11.5 shoots/m^{-2} (mean ± 95% confidence interval) were pulled by 10 June in areas frequented by geese. Shoot pulling after this date was much less intense.

Cumulative production of shoots between 14 June 1985 and 31 August 1985, expressed proportionally as for *C. subspathacea*, did not differ significantly between pooled grazed and pooled ungrazed plots (Table 1). However, there was significant heterogeneity among ungrazed plots (G-tests). When each exclosed plot was treated separately, one had significantly less production than did the pooled grazed plots (G_{1df} = 12.37**).

Between 31 August 1985 and 17 June 1986, the production of shoots did not differ between grazing treatments (Table 1).

Between 20 June 1986 and 26 August 1986, mean cumulative production per 5 × 5 cm subplot was 1.02 shoots in grazed plots and 0.90 shoots in ungrazed plots. These values did not differ significantly (t_{98} = 0.446).

c. *C. aquatilis*

Most of the pulling of shoots of *C. aquatilis* by geese occurs during spring melt. Shoot pulling may be very intense; about 175.0 ± 22.9 shoots/m^{-2} (mean ± 95% confidence interval) were pulled by 10 June 1986 in areas frequented by geese. Very little shoot pulling occurred after this date.

There was little evidence that shoot production responded to grazing treatment. Between 18 June 1986 and 28 August 1986, production amounted to means of 304 and 267 shoots per m^2 in grazed and exclosed plots respectively. This difference was not significant (t_{46} = 0.653).

Discussion

Previous studies at La Pérouse Bay have demonstrated that grazing by geese increases the net annual above-ground primary production of *Carex subspathacea* and *Puccinellia*

phryganodes on the salt marsh by 30 to 110%, depending on the year (Cargill and Jefferies, 1984b; Bazely, 1984). This increased production is not a consequence of grazing *per se*, but a result of geese accelerating nitrogen cycling and promoting nitrogen fixation by blue-green algae in this nitrogen-limited environment (Cargill and Jefferies, 1984a,b; Bazely and Jefferies, 1985). In addition, geese benefit the early successional grazing flat community by preventing litter buildup and eliminating invading plant species, consequently retarding succession (Cargill and Jefferies 1984b; Bazely and Jefferies, 1986; Jefferies, 1987). Conversely, geese also locally destroy areas of forage species in both fresh and saltwater habitats at La Pérouse Bay, leading to areas of bare sediment and probably moss carpets (Jefferies, 1987; Kotanen, pers. obs.). Destruction of forage vegetation by geese has also been reported in other locations, sometimes on a large scale (e.g., Tikhomirov, 1959; Kerbes, 1982; Jefferies and Kerbes, 1985). These observations do not contradict the earlier picture of stable plant-herbivore interaction at La Pérouse Bay, but do suggest that the maintenance of heavily-used forage communities may depend on a delicate balance of interacting factors which is not universally achieved. The data from the study described here provide evidence on the importance and interactions of some of these factors.

Both *Carex subspathacea* and *C* × *flavicans* strongly respond to herbivory with increased production of leaves. No evidence was observed in either of these species or in *C. aquatilis* for consistently increased production of shoots; if a positive response occurs at all, it must either be very weak or occur over a longer interval than one season. Consequently, these sedges seem better able to respond to grazing than to the pulling or grubbing of shoots.

Even if compensatory shoot production occurred, the loss of shoots might be expected to be a more serious cost than the loss of leaves. Leaves are quickly replaced from undamaged basal meristems, while low rates of shoot production imply that the loss of a shoot has a much longer-lasting effect and results in a greater loss of potential photosynthate. Seasonal variation in food choice by the geese may increase this cost. Since most grubbing of shoots occurs in the early spring, before significant leaf growth has occurred, these developing shoots may contain a large proportion of the nutrients available for the plants' growth. Thus, because of both the cost and the lack of an adequate growth response, any increase in the intensity of shoot loss may be expected to affect these sedge communities detrimentally.

Shoot pulling tends to be distributed patchily, especially in freshwater communities where ponds that thaw earlier are intensely used. Such variation results in the destruction of restricted areas, even while the mean intensity of shoot pulling for the habitat remains quite low. A patchy foraging pattern may also fail to increase growth through accelerated nitrogen cycling, since the frequent movement of geese to different areas could lead to the continuous export of nitrogen from heavily used patches.

Interyear variation in the intensity of the grubbing of shoots may also significantly influence community persistence. Spring migration of geese is influenced by weather; poor conditions cause migrants to remain at relatively southern locations, such as La Pérouse Bay, for days or weeks, greatly increasing herbivore pressure. In addition, a cold spring prevents leaf growth and traps unused nutrients in dormant shoots and rhizomes, encouraging the pulling of shoots and reducing the accumulation of photosynthate necessary for the replacement of removed tissue. A run of several poor years can be expected to lead to significant habitat degradation. Conversely, if foraging intensities change significantly between some years, any response in shoot production on a timescale greater than one season would be unlikely to be appropriate.

Differences in the demography of leaves between *C. subspathacea* and *C.* × *flavicans* suggest that these species differ in their ability to tolerate herbivory, either because of intrinsic differences or because of differences between their habitats. Most Arctic sedges have leaves that live for at least one growing season (Shaver and Billings, 1975; Jonasson and Chapin, 1985; Fetcher and Shaver, 1983). This is true for *C.* × *flavicans* and probably also for *C. aquatilis* at La Pérouse Bay. In comparison, the lifespans of leaves of *C. subspathacea* are extremely short. Although the longer lifespans of leaves of *C.* × *flavicans* might allow more efficient internal recycling of nutrients (Coley *et al.*, 1985; Jonasson and Chapin, 1985), they may imply a greater cost associated with grazing since the lost tissue is likely to represent a greater proportion of both annual growth and the internal nutrient pool (Coley *et al.*, 1985). Long lifespans also suggest responses to fluctuations in grazing intensity will be relatively sluggish.

A final feature that strongly influences the behaviour of forage communities is the average intensity of herbivory. There is little doubt that the removal of tissue by herbivores is detrimental in itself; the maintenance or enhancement of production and the persistence of heavily used forage species are unusual events, depending on the existence of some factor that can compensate for this loss. The critical importance of such factors is not always recognized, frequently leading to invalid generalizations across fundamentally different systems, e.g., Belsky (1986). As previously mentioned, the critical compensating factor in saltmarsh habitats at La Pérouse Bay is the increase in available nitrogen associated with grazing.

Either too small a nitrogen supply or too much herbivory might cause the production of this forage community to decline. Consequently, one might predict a range of intermediate levels of grazing that increase production (McNaughton 1983). By varying the length of time that experimental swards were exposed to grazing by captive goslings, David Hik (unpublished data) has demonstrated such a relationship between grazing and production in the saltmarsh community at La Pérouse Bay. Increased production is less likely to be maintained in the local freshwater sedge meadows. In the spring, exceptionally intense herbivory in these communities is associated with spring flooding which is likely to remove any soluble nitrogen freed by the geese. During the summer, the relatively low density of geese in freshwater habitats may likewise not result in a significant stimulation of growth that greater densities of geese produce on the saltmarsh.

On a larger scale, very high densities of geese appear to cause the complete collapse of forage communities. Between 1973 and 1985, the McConnell River colony near Eskimo Point, Northwest Territories (Figure 1) has both declined in size from 163,000 pairs to 132,000 pairs, and also moved

outwards from its former centre (Kerbes, 1974, 1982, unpublished data; Jefferies, 1987). Ground surveys of the vegetation in this area in 1985 and 1986 indicate that the sedge meadow communities that were formerly abundant near the colony centre have been destroyed and degraded, exposing the underlying peat (Jefferies and Kerbes, 1985; Jefferies, Kerbes and Kotanen, unpublished data). Field observations suggest that excessively intense herbivory by the large population of geese is responsible for this change. The relatively small Snow Goose colony at La Pérouse Bay has rapidly grown from about 1200 pairs in 1968 to about 7000 pairs in 1986 (Cooke *et al.*, 1982; Cooke and Rockwell, unpublished data); if this increase continues, it will be interesting to observe if large-scale degradation of forage communities will occur there as well. Perhaps the moss carpets of freshwater areas and the unvegetated patches common in the salt marsh are the precursors of large-scale change. It is possible that Snow Goose colonies go through regular cycles of establishment, growth, habitat, destruction and decline or relocation. In addition to being of interest in themselves, such cycles could have considerable economic and sociological repercussions. For example, the Inuit of Eskimo Point use the local colonies as major sources of both meat and eggs. Snow Geese are also heavily hunted in southern Canada and especially the southern U.S. where they are one of the most important of gamebirds. The existence of boom and bust cycles would both affect traditional Inuit hunting practices and greatly complicate any effort to protect breeding colonies as a conservation measure.

The relationships between herbivores and their food species are subtle and complex. Even in a relatively simple system such as that described in this paper, a large number of interacting factors must be invoked in order to gain any real understanding of community dynamics. Given such complexity, incautious generalization across different plant-herbivore systems is likely to be more misleading than valid. On a more positive note, it is equally likely that detailed analyses of systems such as La Pérouse Bay may not only illuminate their behaviour, but may also provide insight into factors likely to be important in other systems.

Acknowledgments

The data discussed in this paper were collected as part of my M.Sc. thesis, under the supervision of R.L. Jefferies, whom I would particularly like to thank for his help and support. David Hik allowed me to cite unpublished data; Dr. E. Ball, W. Crins, and Dr. J. Cayouette helped to identify my carices. Helen Sadul, Martin Morgan, Joan Montagnes, Janet Curren, and students and staff of the Queen's University Tundra Biology Station and the Churchill Northern Studies Centre provided invaluable assistance.

I would also like to thank the Canadian Northern Studies Trust, NSERC, the Canadian Wildlife Service, the Department of Indian and Northern Affairs, and the Arctic Institute of North America for their financial support. Special thanks are due to Brenda Missen, who typed the manuscript.

References

Anon 1986. SPSSX User's Guide (Release 2.1). McGraw-Hill, New York.

Bazely, D.R. 1984. Response of salt-marsh vegetation to grazing by lesser snow geese (*Anser caerulescens caerulescens*). Unpublished M.Sc. thesis, Department of Botany, University of Toronto, Canada.

Bazely, D.R. and Jefferies, R.L. 1985. Goose Faeces: a source of nitrogen for plant growth in a grazed salt marsh. Journal of Applied Ecology 22:693–703.

Bazely, D.R. and Jefferies, R.L. 1986. Changes in the composition and standing crop of salt-marsh plant communities in response to the removal of a grazer. Journal of Ecology 74:(in press).

Belsky, A.J. 1986. Does herbivory benefit plants? A review of the evidence. American Naturalist 127:870–892.

Berkson, J. and Gage, R.P. 1950. Calculation of survival rates for cancer. Proceedings of the Mayo Clinic 25:270–286.

Cargill, S.M. and Jefferies, R.L. 1984a. Nutrient limitation of primary production in a sub-arctic salt marsh. Journal of Applied Ecology 21: 657–668.

Cargill, S.M. and Jefferies, R.L. 1984b. The effects of grazing by lesser snow geese on the vegetation of a sub-arctic salt marsh. Journal of Applied Ecology 21:669–686.

Coley, R.D., Bryant, J.P., and Chapin, F.S.III. 1985. Resource availability and plant antiherbivore defence. Science 230:895–899.

Cooke, F., Abraham, K.F., Davies, J.C., Findlay, C.S., Healey, R.F., Sadura, A., and Seguin, R.J. 1982. The La Pérouse Bay Snow Goose Project — A 13-Year Report. Unpublished report of the Department of Biology, Queen's University, Kingston, Ontario.

Crawley, M.J. 1983. Herbivory. University of California Press, Berkeley.

Fetcher, N. and Shaver, G.R. 1983. Life histories of tillers of *Eriophorum vaginatum* in relation to tundra disturbance. Journal of Ecology 71:131–147.

Harper, J. 1977. Population Biology of Plants. Academic Press, London.

Jefferies, R.L. 1987. Vegetational mosaics, plant-animal interactions, and resources for plant growth. In Plant Evolutionary Biology (Editors: Gottlieb, L.D. and Jain, S.K.). Chapman and Hall Ltd., London.

Jefferies, R.L., Jensen, A., and Abraham, K.F. 1979. Vegetational development and the effect of geese on vegetation at La Pérouse Bay, Manitoba. Canadian Journal of Botany 57:1439–1450.

Jefferies, R.L. and Kerbes, R.H. 1985. The effects of foraging by geese on the vegetation in the coastal vicinity of Eskimo Point, N.W.T. Unpublished report to the Canadian Wildlife Service.

Jonasson, S. and Chapin, F.S. III. 1985. Significance of sequential leaf development for nutrient balance of the cotton sedge *Eriophorum vaginatum* L. Oecologia (Berlin) 67:511–518.

Kerbes, R.H. 1974. The nesting population of Lesser Snow Geese in the eastern Canadian Arctic: A photographic inventory of June 1973. Canadian Wildlife Service Report Series Number 35. Environment Canada.

Kerbes, R.H. 1982. Lesser Snow Geese and their habitat on west Hudson Bay. Le Naturalist Canadien (Revue d'Écologie et de Systématique) 109:905–911.

Kotanen, P.M. and Jefferies, R.L. 1987. The leaf and shoot demography of grazed and ungrazed plants of *Carex subspathacea*. Journal of Ecology /5:(In press).

McNaughton, S.J. 1983. Compensatory plant growth as a response to herbivory. Oikos 40:329–336.

Pielou, E.C. 1969. An Introduction to Mathematical Ecology. Wiley, New York.

Shaver, G.R. and Billings, W.D. 1975. Root production and root turnover in a wet tundra ecosystem, Barrow, Alaska. Ecology 56:401–409.

Sokal, R. and Rohlf, F.J. 1981. Biometry (Second Edition). Freeman, New York.

Tikhomirov, B.A. 1959. Relationship of the Animal World and the Plant Cover of the Tundra. Publication of the Botanical Institute, Academy of Science of the USSR. Moscow and Leningrad. Translated by Issakoff, E. and Barry, T.W. Edited by Fuller, W.A. The Boreal Institute, Edmonton, Canada.

ENERGETICS OF THE SUB-ICE AMPHIPOD *WEYPRECHTIA PINGUIS*

Patricia N.B. Lewis

Department of Zoology, University of Manitoba, Winnipeg, Manitoba R3T 2N2

Level: Master's

Abstract

The amphipod *Weyprechtia pinguis* is an important member of the Arctic Ocean sub-ice food chain, providing a link between the primary producers (ice algae) and higher animals such as Arctic cod (*Boreogadus saida*) and the ringed seal (*Phoca hispida*). *Weyprechtia* is known as a grazer of sub-ice diatoms, but little else has been previously reported on its feeding ecology.

In this study, ingestion rate and assimilation efficiency were determined for *Weyprechtia* during the spring sub-ice algae bloom in Barrow Strait. Ingestion rate was estimated from the gut evacuation rate, which was measured by following the loss of Silica from the gut with time after feeding. The rate of Silica loss over time multiplied by the Silica content of a full gut gives the ingestion rate. The average feeding rate for adult *Weyprechtia* from mid-April to mid-June was 0.41 μg Silica · animal^{-1} · hr^{-1}, or 3.78 μg dry weight algae · animal^{-1} · hr^{-1}. No trend of increase or decrease in ingestion rate was observed over the season.

Assimilation efficiency was measured by comparing the ratio of Silica: dry weight in the natural food, and in the feces collected during the feeding rate experiments. In May and June, the average assimilation efficiency was 77.0%.

Key words: *Weyprechtia pinguis*, amphipod, feeding, sub-ice.

Résumé

L'amphipode *Weyprechtia pinguis* constitue un élément important de la chaîne trophique sous-glacielle de l'Océan arctique, car c'est le chaînon entre le producteur primaire (les algues nivales) et des organismes vertébrés comme la morue arctique (*Boreogadus saida*) et le phoque annelé (*Phoca hispida*). On sait que le *Weyprechtia* se nourrit de diatomées sous-glacielles, mais on n'avait pas publié grand-chose au sujet des caractéristiques de leur assimilation.

Au cours de l'étude, l'auteure a mesuré les quantités de nourriture absorbées par unité de temps par *Weyprechtia*, et leur taux d'assimilation au cours de la multiplication printanière des algues sous-glacielles dans le détroit de Barrow. Elle a évalué les quantités absorbées en fonction des quantités de résidus excrémentiels, mesurées par les déperditions intestinales de silice après les repas. Cette déperdition de silice par unité de temps, multipliée par le poids de silice contenu dans un intestin plein, donne la quantité absorbée. La quantité horaire moyenne absorbée par le *Weyprechtia* adulte entre la mi-avril et la mi-juin est de 0,41 μg de silice · animal^{-1} · h^{-1}, ou 3,78 μg en poids sec d'algue par animal et par heure. On n'a observé aucune tendance à la diminution ou à l'augmentation de cette quantité absorbée au cours de la saison. L'auteure a calculé le taux d'assimilation en comparant la proportion de silice dans l'aliment naturel (en poids sec) et dans les déjections recueillies, au cours des expériences sur les quantités absorbées. En mai et juin, le taux moyen d'assimilation était de 77,0%.

Mots-clés: *Weyprechtia pinguis*, amphipode, absorption de nourriture, sous-glaciel.

NORTHERN RESOURCE DECISION-MAKING: A CASE STUDY OF THE FARO MINE, YUKON TERRITORY

Bruce A. Lourie

Faculty of Environmental Studies, York University, North York, Ontario M3J 1P3

Level: Master's

Abstract

The Faro Mine (ex-Cyprus Anvil Mine) has resumed production in the Yukon after a four year shut-down. The mine is the single largest employer in the Territory. Depressed metal prices combined with high operating costs forced the shut-down. Now under new ownership, a number of significant changes have been made permitting economic recovery of the ore.

Through a series of interviews with the various parties involved, data has been gathered in an attempt to analyse the complicated nature of northern resource decision-making. A multidisciplinary approach has been adopted to understand the economic, social, political and environmental implications of re-opening the mine.

Four key issues have been identified, each of which had to be resolved in order for the mine to re-open: 1) Reduced

power rates had to be negotiated with the Northern Canada Power Commission. 2) Changes to the water licence were necessary revoking the existing mine abandonment plan. 3) A more economical mode of transportation was required. 4) Labour costs had to be reduced significantly. The resolution of each issue required a considerable amount of political involvement, including the services of many government departments at various levels of government. Several viewpoints are explored, with the majority favouring the mine re-opening.

Key words: Northern mining development, lead-zinc mines, resource decision-making, Cyprus Anvil, Faro, Yukon.

Résumé

Au Yukon, la mine Faro (naguère Cyprus Anvil Mine) a repris l'extraction, après une fermeture de quatre années. Cette mine est le plus important employeur du Yukon. La fermeture avait été imposée par la chute du prix des métaux et des frais d'exploitation très élevés. Les nouveaux exploitants de la mine ont introduit d'importantes modifications qui ont permis de reprendre une extraction rentable du minerai.

L'auteur a mené une série d'entretiens avec les divers intéressés, et il a recueilli des données en vue d'analyser la nature complexe du processus décisionnel en matière d'exploitation des ressources du Nord. Il a choisi une approche pluridisciplinaire afin d'appréhender les conséquences économiques, sociales, politiques et environnementales de la remise en exploitation de la mine.

L'auteur a mis quatre problèmes cruciaux en évidence, et chacun d'entre eux devait être résolu avant qu'on puisse rouvrir la mine: 1) il fallait obtenir des tarifs réduits pour l'électricité, grâce à des négociations avec la Commission hydroélectrique du Nord canadien; 2) il était nécessaire de modifier le permis d'utilisation des eaux, en annulant le plan antérieur de fermeture de la mine; 3) il fallait trouver un mode de transport plus économique, et 4) il fallait réduire notablement les coûts de main-d'oeuvre. La résolution de chaque problème a nécessité l'intervention des autorités politiques et de nombreux services de plusieurs niveaux d'Administration. L'étude analyse plusieurs points de vue, dont la plupart favorisaient la réouverture de la mine.

Mots-clés: Aménagements miniers dans le Nord, mines de plomb & zinc, processus décisionnel en matière de ressources, Cyprus-Anvil, Faro, Yukon.

Introduction

In June of 1982 the Cyprus Anvil Mine (now called the Faro Mine), ceased production. For 13 years the mine had supported the Yukon representing 40 per cent of its economic output and employing (directly and indirectly) 15 per cent of its workforce. The shutdown was therefore devastating for the Yukon economy. The Faro Mine resumed production in June of 1986, after a year of negotiations which aroused some degree of controversy.

The mine is an open pit operation located at the Town of Faro, approximately 200km northeast of Whitehorse. Once one of the largest lead-zinc mines in the world, the Faro Mine employed nearly 750 workers at its peak. Curragh Resources Corporation purchased the mine from Dome Petroleum to facilitate the re-opening.

The objective of this paper is to outline the economic, social, political and environmental implications of re-opening the Faro Mine, by examining the series of events and decisions which led to the mine's re-opening. Information was gathered primarily through interviews with the people and organizations involved in the process. Distinguishing between economic, social, political and environmental factors is indeed a difficult task. In northern resource development it seems every decision is political in an attempt to boost the economy with a minimum of social and environmental disruption. Accepting the fact that a tremendous amount of overlap exists between each of the four domains, the issues will be categorized and discussed according to their dominant focus.

Execution of the re-opening

Financing

Cyprus Anvil Mining Corporation (CAMC), a subsidiary of Dome Petroleum Limited, owned and operated the mine at Faro when it was shut down in 1982. The mine was previously owned by Hudson Bay Oil and Gas Corporation Limited, which Dome Petroleum bought in 1982. Dome's decision to sell was therefore made when it had owned CAMC for under six months. However, CAMC was $150 million in debt, and the mine was continuing to lose money. Therefore, Dome decided to sell the entire operation; mine, mill, equipment and town.

A number of mining companies initially expressed interest, but after examining the deal decided too much needed to be accomplished before the mine could operate economically. Four key problems were making the mine uncompetitive: transportation costs were too high, a labour agreement needed to be negotiated, power rates were excessive, and a costly mine abandonment plan was in place. These four obstacles caused prospective buyers to lose interest in the property. In an attempt to make the mine more attractive, a $40 million waste stripping program was initiated in May of 1983, funded jointly by Dome and the federal government. After the completion of the stripping it appeared as though the mine was still not going to sell. In May of 1985, Dome began to contemplate mothballing the operation. Coincidentally, an independent mining executive, Clifford Frame, approached Dome to discuss the possibility of purchasing the mine.

The "purchase price" is often quoted as being approximately $50 million. In actual fact, this figure refers to the amount of money required to bring the mine back into production. No money was paid directly to Dome. Instead, Dome will receive a percentage of future net profits. Furthermore, the federal government has agreed to write-off much of Cyprus Anvil's debt, and to incorporate the remaining debt within Dome's huge debt.

Curragh Resources Corporation (the company formed by Frame to purchase Cyprus Anvil) raised $20 million. In addition, a $15 million line of credit has been arranged with banks. The bank financing has been guaranteed 85 per cent by the Government of Yukon, which has in turn been 90 per cent guaranteed by the Government of Canada. An additional $5.4 million in "territorial incentives" and a $3 million federal grant assisted Curragh in the re-opening. The territorial incentives included the purchase of 122 homes in Faro for $1.6 million and the provision of a second mortgage to

Curragh of $3.4 million on 162 additional properties. The $3 million federal grant was created specifically for Curragh under the federal Economic Development Agreement. The grant was designed to assist any mine which could immediately employ 100 people for a minimum of five years; Curragh was the only company in the Yukon able to meet this requirement.

With the financing in order, the task of resolving the four key obstacles (transportation, power, labour and mine abandonment) remained.

Transportation

Throughout Cyprus Anvil's operation, ore concentrate was transported from Faro to Whitehorse by truck, then loaded on a train and taken to the Pacific Ocean port at Skagway, Alaska. Transporting the concentrate the relatively short rail distance of 230km over narrow-gauge tracks, combined with having to transfer the load from truck to train in Whitehorse, resulted in a hopelessly inefficient transportation system. The most efficient transportation method was clearly to leave out the rail link entirely and transport the concentrate the full distance by truck. This however, signified the permanent closure of the White Pass and Yukon Railway, which had shut down in 1983 as a result of the Faro Mine closure. In addition, much larger trucks were to be used, increasing the efficiency of the operation, but adding to the deterioration of the highways. The use of trucks necessitates year round maintenance of the road to Skagway, and increased maintenance costs. The federal government agreed to upgrade the highway, while the Territory will be maintaining it. It is expected that fuel taxes and a one dollar per tonne concentrate fee will cover the additional highway maintenance costs.

Labour

The Cyprus Anvil Mine had a reputation of being one of the highest paying mines in the world. High salaries, inexpensive housing (owned by CAMC), health and dental plans, and eight hour shifts all contributed to the mine's high operating costs and eventual shutdown. In the late 1970's when metal prices and profits were high, unions often had the upper hand in contract negotiations. Since there was plenty of money to go around, companies like Cyprus Anvil frequently consented to even the most trivial of union demands; including the reversal of the normal warning system, so that red lights were on when the mill was running and green lights signified a stoppage.

The sudden drop in metal prices and the subsequent recession of 1981, left Cyprus Anvil with a payroll far too large to manage, forcing a lay-off of the majority of the workforce.

In order to re-open the mine, Curragh Resources made several signficant changes to improve economic efficiency. By implementing a "hot change", whereby the mine operates on two 12-hour shifts with no equipment shutdowns between shifts, productivity has been increased by between 25 and 30 per cent. Wages at the now non-unionized operation are approximately half of what they used to be. All housing is owned or rented privately by the workers and there are no elaborate health plans. Consequently, costs have been reduced substantially.

Power

A further requirement of Curragh Resources was that the Northern Canada Power Commission (NCPC) reduce their hydro rates significantly. Curragh argued that since they were a "steady use" customer, their rates should reflect the cheaper power they consume. Expensive peak power, they argued, is required by the residents of Whitehorse, not the mine. NCPC cut Curragh's power rates in half, while increasing all other customers' rates by five per cent.

Mine abandonment plan

It is a requirement of all mines in the Yukon, under the *Northern Inland Waters Act*, to provide a mine abandonment plan when applying for a water licence. Cyprus Anvil was committed to a $51 million (1981$) abandonment plan, which with the sale of the mine would become the responsibility of Curragh. This was clearly unacceptable to Curragh and more critically, to the investors and bankers behind Curragh. Therefore, Curragh urged Cyprus Anvil to have the water licence amended, revoking the abandonment plan. Curragh was very blunt in its demands stating "if these licensing conditions are not amended now, the $50 million of new money raised will disappear, the transaction will not be completed, and the mine will not re-open" (from a letter to Cyprus Anvil, September 5, 1985). The Yukon Territory Water Board (YTWB) agreed in an "emergency amendment" (an issue in itself) to remove the abandonment plan, extend the required date for tailings capping or flooding, and permit an increase in water consumption.

With the four major issues now resolved (for Curragh), the way was clear for the signing of the deal. The implications of some of the decisions had yet to be realised.

Effects of the re-opening

Economic benefits

Clearly, the primary reason for both the federal and territorial governments' keen involvement in the re-opening of the Faro Mine was to create jobs. For the Government of Yukon particularly, unemployment was a major concern. Mine shutdowns forced the unemployment rate to nearly 20 per cent. Re-opening the Faro Mine was considered to be the most cost-effective method of creating a large number of "instant" jobs. Curragh estimates 375 people will be employed at the mine, with an additional 400 employed in support services. This makes up nearly 10 per cent of the Yukon's workforce.

The Government of Yukon will not benefit directly from the mine revenues, since all mineral taxes and royalties are federal. Fuel tax is the major financial reward for the Territory, however it will be consumed entirely by the higher highway maintenance costs as a result of the increased trucking.

One benefit of the year round operation of the Klondike Highway will be reduced shipping costs for goods entering and leaving the Territory. This should have a positive effect on the economy. However, concern was expressed that heavy truck traffic on the highway between Carcross and Skagway may discourage vacationing motorists. Since tourism is the number two "industry" in the Yukon (after mining) any

potential threat to tourism is taken very seriously. One would imagine that word of an improved highway would actually increase tourist traffic, not the opposite.

Placing the Faro Mine in a national context presents a very different situation. Canada's five major lead-zinc producers were strongly opposed to the re-opening of the mine. Together, they approached the federal government urging them not to assist Curragh. They argued that it would not be economically wise to bring on-stream another lead-zinc mine in Canada, when the existing mines were barely able to operate due to depressed base metal prices. They believed additional concentrate on the market would only succeed in driving the prices even lower. Moreover, they suggested that the jobs created in the Yukon would be displacing workers elsewhere in Canada. Pine Point Mines Limited (Cominco) submitted that the re-opening of Faro would result in an earlier shutdown date for the Pine Point Mine. Falconbridge officials announced the shelving of a proposed development in northern Ontario "in part" due to the Faro decision. Clifford Frame labelled the group "a cartel", dismissing their arguments as being selfish and hypocritical. It is difficult to assess what impact, if any, the re-opening of Faro will have on the mining industry in the rest of Canada. It would appear that the benefits to the Yukon outweigh the costs which may be incurred elsewhere in Canada.

Two positive aspects of the re-opening for the country, are increased revenues through mineral taxes and royalties, and a slight reduction in Canada's trade deficit, since Faro concentrate was successfully sold to far eastern markets. In relative terms, each of these factors is quite insignificant, although still beneficial.

Social effects

The provision of jobs cannot help but be perceived as beneficial to Yukon's social framework. However, the situation is not as wonderful as the statistics may imply. Curragh contracts out the majority of the work to a personnel company, which is in charge of payroll, hiring and other employee-related activities. Consequently, the mine is non-unionized and wages are nearly half of what they were prior to the shutdown. Low wages combined with increased housing and transporation costs for workers has resulted in a high turnover rate, and at least one small labour dispute. The workers expect everything to be the same as it was when Cyprus Anvil owned the mine. However, the atmosphere is very different now. The emphasis is on reducing costs and increasing productivity; something Curragh has done very successfully. The same quantity of ore can now be produced with 63 per cent of the pre-shutdown workforce.

Curragh Resources has no intention of keeping the mine non-unionized. They have adopted a very open attitude with the workers, explaining that the company has a very limited amount of money to spend, and that as soon as profits are generated, workers will receive their share. It is difficult to predict whether the mine will become unionized or not, but it would appear that there are no advantages (but perhaps disadvantages) to the presence of a union.

In their agreement with the governments, Curragh is committed to make an effort at hiring Yukoners and natives. However, there is no mechanism to measure their "effort" or enforce their commitment. Based on the observed priorities of Curragh, it would seem unlikely that they would jeopardize efficiency in any way, thereby hiring only the most qualified workers, regardless of background.

Political involvement

The fate of any large industrial development in the North ultimately rests with politicians. Without the determination of Yukon Government Leader, Tony Penikett and the signature of then federal Northern Affairs Minister, David Crombie, the re-opening of the Faro Mine would not have been possible. Virtually all of the issues discussed required an important political decision. Selecting the option to transport ore concentrate entirely by truck means the railway will likely remain closed permanently, to the dismay of many Yukoners. Although it was a politically sensitive issue, politicians were faced with little other choice if they wanted to see the mine open. Likewise, for NCPC to cut the mine's hydro rates in half, while raising the rates of the rest of the territory, another politically unfavourable decision had to be made. Again, Curragh Resources presented the decision-makers with no other choices. Finally, in a decision which angered conservationists, notably the Yukon Conservation Society, the Yukon Territory Water Board agreed in an emergency amendment to permit the Faro Mine to operate without an abandonment plan in place. Clearly, each of these decisions required a certain trade-off. Evidently, politicians viewed the re-opening of the mine as the number one priority, and that the sacrifices made would be acceptable.

Environmental implications

The primary concern of environmentalists was the Water Board's decision to revoke the mine abandonment plan. The Yukon Conservation Society had worked hard to see that the water licence for Cyprus Anvil included a comprehensive abandonment plan, which included an intricate (and costly) system of dams and settling ponds. The objective of the system is to reduce the flow of toxic effluent into the water system. Furthermore, the abandonment plan provides for the permanent closure of the mine, by outlining a detailed plan for containing and monitoring the tailings area, to prevent acid generation.

Without an abandonment plan in place, it is more difficult, and in the end more costly, to manage the long term disposal of mine waste. It is for this reason that the Yukon Conservation Society and Environment Canada expressed concerns about permitting Curragh to operate without addressing the issue of permanent abandonment. The Water Board consented to the wishes of Curragh, upon the condition that Curragh submit an abandonment plan by December 31, 1986. Curragh has set up a "Trusteed Environmental Fund" whereby 25 cents will be set aside for every tonne of concentrate shipped. This is predicted to generate $7.5 million in 25 years, considerably less than the $51 million Cyprus Anvil agreed to spend.

The Yukon Conservation Society was more concerned with the process of granting the amendment, than with the decision itself. Normally, all water licence applications are open to public review and hearings. However, Cyprus Anvil requested an emergency amendment, in order to hasten the process by eliminating the requirement for public hearings. The Yukon Conservation Society argued that the situation

was not an emergency, and therefore the emergency amendment was not applicable. Curragh, on the other hand, reasoned that since deadlines for some of the financial agreements were quickly approaching, the situation was in fact an emergency. Approval by the Minister of Northern Affairs was granted, allowing the Water Board to proceed without public intervention.

Conclusions

Decision-makers involved in the re-opening of the Faro Mine were faced with many difficult choices. Support for the re-opening was very strong in the Yukon. Unemployment was high and the economy depressed, re-opening of Faro was therefore seen as a solution to everyone's problems. Consequently, nobody wanted to be blamed for obstructing the process. Both Cyprus Anvil and Curragh Resources applied pressure on the organizations participating in the negotiations, further intimidating them.

The economic and social benefits of the re-opening were perceived to outweigh the sacrifices that were made. Perhaps if the government was a little firmer the sacrifices could have been less significant.

Comparisons between the present operation of the Faro Mine with the Cyprus Anvil days are of little use. The choice was between Faro as it is now, or no mine at all. A vast majority of Yukoners seem happy that the mine has re-opened and few people regret the decisions that were made. Only after several years of operation will the full implications of the decisions be realized. For now, the re-opening of the Faro Mine is viewed as a success.

THE FUTURE OF PARKS CANADA NORTH OF 60

Shona MacLachlan

Faculty of Environmental Studies, York University, North York, Ontaro M3J 1P3

Level: Master's

Abstract

The paper looks at northern National parks in the context of conservation and discusses Auyuittuq National Park Reserve as a case study.

Parks Canada's involvement North of 60 currently comprises the three reserves of Auyuittuq, Kluane, and Nahanni and Northern Yukon National Park. Although Parks Canada has plans to establish at least fifteen more parks in the North, the paper argues that national parks may not provide the best protection for our northern wilderness. The *National Parks Act* (1930) is designed to meet both public use as well as to serve as a means of preservation.

Auyuittuq National Park Reserve (ANPR), located almost entirely within the Arctic Circle, is Canada's northernmost park. By using ANPR as a case example, it is demonstrated that other conservation initiatives such as ecological sites and wildlife areas would be better suited to satisfying the unique conservation objectives of Northern Canada.

Key words: National Parks, conservation, wilderness, Baffin Island.

Résumé

L'étude porte sur les parcs nationaux dans une perspective de protection rationnelle, et décrit le cas particulier du Parc national d'Auyuittuq.

Le domaine d'activité de Parcs Canada au nord du 60^{e} parallèle englobe actuellement les parcs nationaux d'Auyuittuq, de Kluane et de Nahanni, et le Parc national du Yukon septentrional. Bien que Parcs Canada ait élaboré des plans de création d'au moins 15 autres parcs dans le Nord canadien, l'auteure estime que ce n'est peut-être pas le meilleur moyen de protéger ces territoires.

La Parc national d'Auyuittuq (ANPR), qui se trouve presque entièrement au Nord du cercle arctique, est actuellement le parc le plus septentrional de notre pays. En présentant son dossier, l'auteure recommande d'autres initiatives protectrices, comme la délimitation de réserves écologiques et fauniques, meilleurs moyens, selon elle pour atteindre les objectifs de protection particuliers au Nord canadien.

Mots-clés: Parcs nationaux, protection, territoires vierges, île de Baffin.

The fundamental objective for creating national parks is the preservation of nature for future public enjoyment. However nature is a difficult concept since it is always changing. R.D. Lawrence in *Canada's National Parks* (1983) explains:

> It is this ability to change at an exceptionally slow but progressive rate that must be conserved. This means that nature must not be tampered with by man, it must not be violated, it must not be forced to remain static by preservation. If we wish to keep our parks unimpaired they must be allowed to change in their own ways and at their appointed times as they have been doing since the dawn of creation.

This is a formidable task and this objective needs to be re-evaluated in light of future national park establishment in Northern Canada.

Parks Canada

Mandate

Parks Canada is the premier agency in identifying, planning and managing parks in the Canadian North (Nelson *et al.* 1984). Parks Canada's mandate originates from the *National Parks Act* (1930) and the National Parks Policy (1979). The *National Parks Act* states;

> The National parks of Canada are hereby dedicated to the people of Canada for their benefit, education and enjoyment subject to this Act and the regulations and the National Parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations (sec. 4).

Generally, the objective is designed to meet public use as well as to serve as a means of preservation. However, there is always a potential conflict over the inherent duality of the act between use and protection of the environment.

In an attempt to clarify this problem, the 1979 National Parks Policy stressed the primary importance of preservation:

> National Parks are a means of preserving in a natural state, areas which are representative of the major natural environments of Canada . . . In order to enable the continued protection of these areas it is necessary to ensure that visitor activities do not result in harmful changes to ecology or appearance of the landscape (DIAND, 1979).

However, a fundamental problem still exists because policy is not law and until the *National Parks Act* is amended to state that preservation is the primary objective, the duality between use and preservation will remain.

Park establishment

Parks Canada has a systematic selection and management process that it follows. The first stage, systems planning, decides where the parks will be established. Parks Canada has divided Canada into forty-eight natural regions. Within each of these regions, Natural Areas of Significance (NACS) are identified according to defined criteria. Potential parks are selected from these NACS and the goal is to have at least one national park in each natural region. Parks Canada must also consult with native organizations and territorial governments before a national park can be established. In some respects it is easier to establish a national park in the North since the federal government already owns 98% of the land. On the basis of present information the goal for the Canadian North is fifteen national terrestrial parks and at least three national marine parks (DOE, 1983).

Once land has been withdrawn for a park, the second phase of master planning begins. This phase of planning is concerned with where activities should be carried out, what facilities are necessary, and how protection should be accomplished. These types of decisions are the basis for the implementation of the zoning system. Parks can be subdivided into five different zones; Special Preservation, Wilderness, Natural Environments, Recreation and Park Services.

The final phase of the process is management planning where a management plan has been approved and put into effect. The management plan is a framework within which subsequent management implementation and detailed planning will take place. These plans usually last ten to fifteen years with periodic five-year reviews. It should be noted that management plans are only policy statements and can be changed at any time.

Northern parks

How effective has the management process been in the North? To date, there is one National Park and three National Park Reserves, completely North of 60°N. The three reserves of Auyuittuq (22,470 km^2), Kluane (22,000 km^2) and Nahanni (4,766 km^2) were established in 1972. The only national park is the Northern Yukon (10,000 km^2) established in 1984. (Refer to Figure 1 for locations). The only difference between a reserve and a park is that in a reserve the boundaries are not definite because landclaim settlements have not been finalized.

In addition to the park and reserves, five other areas of interest were announced by Parks Canada in 1978; East Arm of Great Slave Lake, Bathurst Inlet, Ellesmere and Heiberg Islands, Pingos at Tuktoyaktuk, and Wager Bay. In two of these areas, Ellesmere Island and East Arm of Great Slave Lake, the federal government has afforded interim protection by prohibiting development in these areas. Both these areas have been given high departmental priority with the Ellesmere proposal merely awaiting final authorization.

Uniqueness of northern parks

Although Parks Canada has plans of creating at least fifteen more national parks, it is argued that national parks may not provide the best protection for our northern wilderness. In the North, Parks Canada is concerned not only with preservation and public use, but also with Inuit interests.

The Inuit have one primary concern regarding future park establishment. They are concerned that parks will leave no room for traditional hunting, trapping, and fishing. A park is an alien concept to the native peoples. For example the *Inuktitut* term for national park is, "the place white men come to play" (Tennent, 1980). The Inuit foresee conflicts if parks are allowed and southern pressure increases to restrict native harvesting. In response to this concern, the *National Parks Act* was amended in 1974 to guarantee native harvesting rights. Nevertheless, the Inuit Tapirisat of Canada still argue that the "wilderness character as commonly defined could ultimately only be preserved at the expense of Inuit hunting" (Tennent, 1980).

In addition, the northern environment is generally more sensitive and vulnerable than southern environments and this makes preservation all the more difficult. Some of these "vulnerable" characteristics of northern ecosystems that need to be taken into consideration are the following; presence of permafrost, slow nutrient cycle, low productivity, low species diversity, few trophic relationships and limited overlap in species niches (Theberge, 1983). Ecological links are spread over vast areas and this means that conservation areas also need to be extensive.

Parks Canada has a difficult task in trying to appease the development interests in the North; economic (non-renewable resource industries), political (the increasing power of the territorial governments), and social (the aspirations of the native peoples for increased control over land uses). Parks Canada must also balance the rights of all Canadians to understand and enjoy their heritage with the rights of the local people to continue their traditional subsistence uses of the

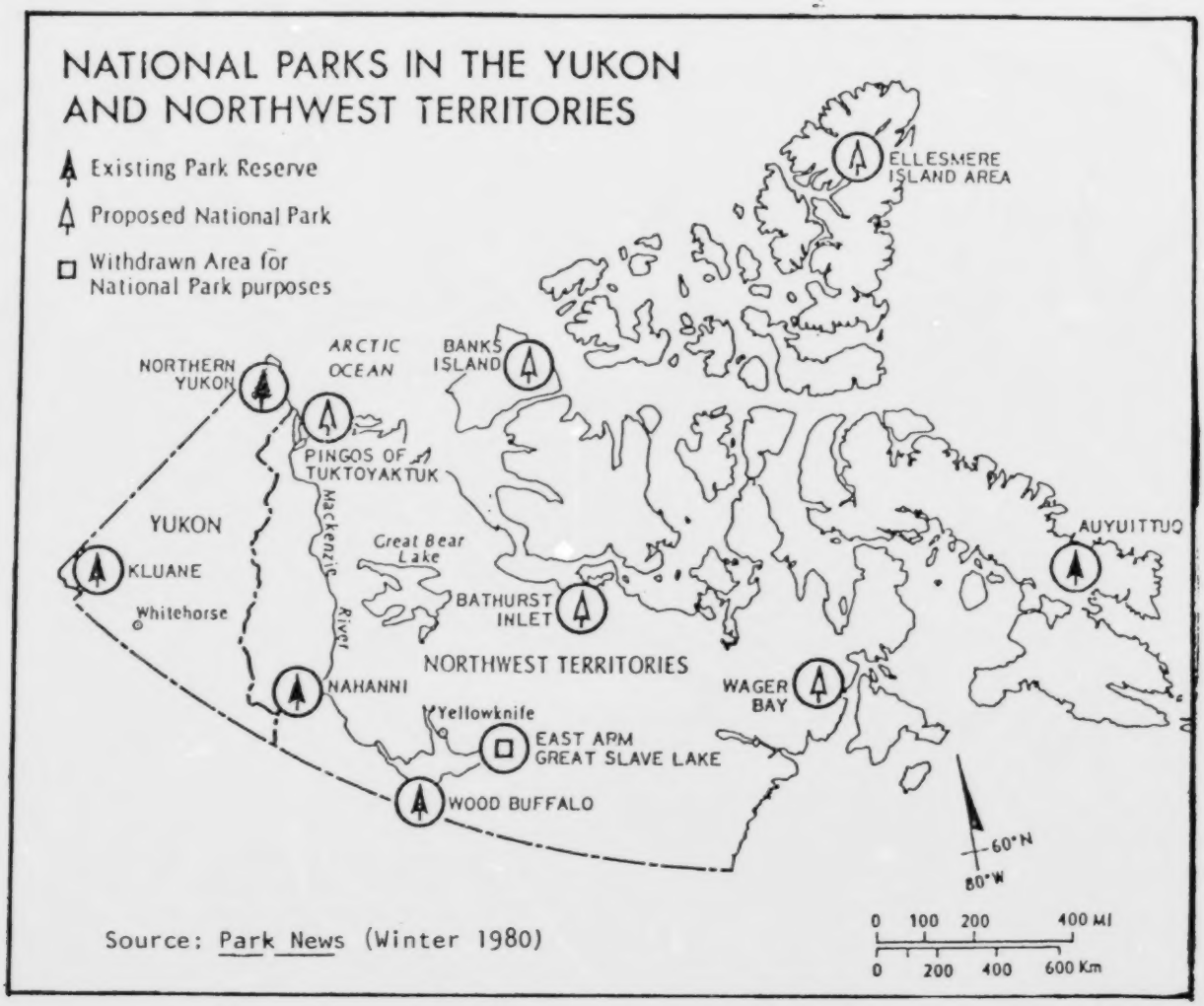


Figure 1. National Parks in the Yukon and Northwest Territories.

land while still protecting the wilderness of the area. Is it realistic to try and achieve all three objectives in Northern Canada?

Auyuittuq National Park Reserve

By using Auyuittuq National Park Reserve (ANPR) as a case study, it has been shown that the dual mandate of use and preservation is not appropriate for the conservation of northern areas.

ANPR is Canada's northernmost park located on the Cumberland peninsula of Baffin Island. The name "Auyuittuq" is the *Inuktitut* word meaning, "the place which does not melt" or "the land that never melts". The purpose of the park reserve in the National Parks System, "is to protect for all time a representative natural area of Canadian significance in the Northern Davis Natural Region and to encourage public understanding, appreciation and enjoyment of this natural heritage so as to leave it unimpaired for future generations" (Parks Canada, Sept. 1982).

ANPR provides representation of the following natural history features of the Northern Davis Region; a mountainous terrain with the greatest Canadian Shield relief, long fjords, an ice cap, glaciers, and Davis Strait shoreline. The park reserve supports a limited number of plant and animal species which have adapted to the harsh environment. Plant species include lichens, mosses and numerous wildflowers. Land mammals found in the reserve include lemming, arctic hare, arctic fox, polar bear and caribou. Marine mammals include ringed, bearded and harp seals. There are only a limited number of bird species found in the reserve, the most common being geese, ducks and shore and sea birds, although gyre and peregrine falcons, snowy owls and ptarmigan can also be observed

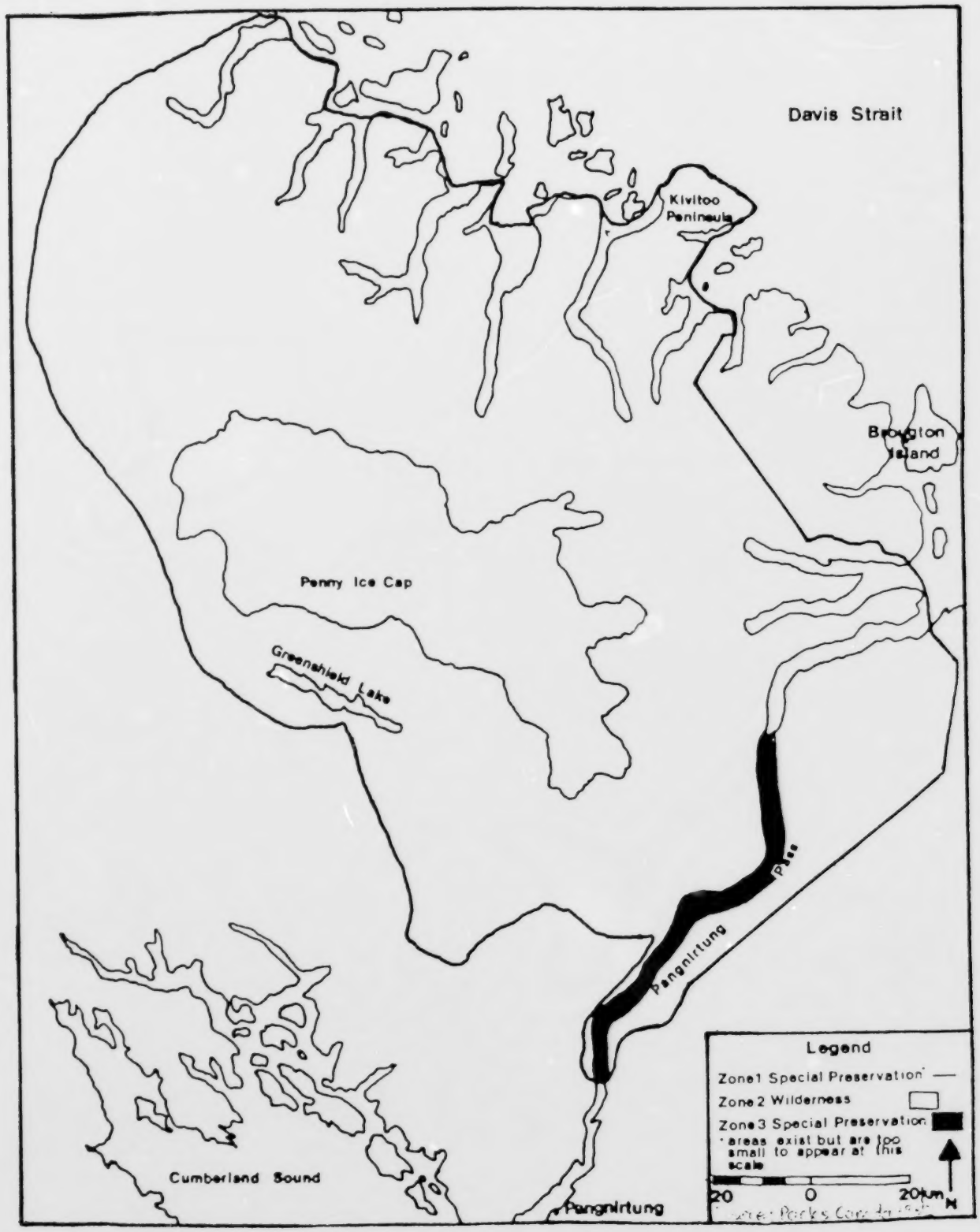


Figure 2. Auyuittuq National Park Reserve.

In examining management problems in ANPR, three park objectives will be evaluated; preservation, visitor use and Inuit interests.

Preservation

In order to protect the environment, ANPR has been divided into three zones, (Figure 2). Zone I or Special Preservation is designed to preserve the environment in an unimpaired condition. Example of Zone I areas are peregrine falcon nesting areas. The majority of ANPR is Zone II or Wilderness. The objective of wilderness zoning is to preserve the natural and wild conditions of the park reserve as well as to provide opportunities for the public to experience the reserve's wilderness. The third type of zoning is Zone III or Natural Environment. The objective of Zone III is to encourage appreciation and enjoyment of the park reserve's features through participation in outdoor recreation activities in a natural environment. Motorized vehicle access is allowed to the two park entrances at the north and south ends of the park. The present zoning system seems adequate for preservation since the majority of visitors stay in the Zone III Area.

According to the Interim Management Guidelines, the park staff is responsible for keeping a record of the floral and faunal resources by noting species distribution, numbers and habitats and if possible, migration routes and patterns (Parks Canada, Sept. 1982). In addition, the staff is responsible for monitoring renewable resource activities. The major problem is that the Inuit wardens are not properly qualified to conduct such inventories and therefore their major responsibility has become patrolling the park for visitor safety. Another factor which precludes instituting a systematic wildlife monitoring program characteristic of southern national parks is the lack of large wildlife populations in ANPR. The populations that do exist are widely dispersed.

Visitor use

ANPR, "encourages appreciation and enjoyment of the harsh unspoiled wilderness" (Parks Canada, Sept. 1982). The park's rugged features provide a challenge to climbers, backpackers and skiers. The existing facility development is kept to a minimum and includes warden stations, emergency shelters and supplies, primitive campgrounds, garbage depots and toilets. These facilities are located at strategic locations along the one 93 km trail that traverses the park from north to south.

From the author's observations, visitor education could be improved in ANPR. Visitors need to be more aware of the "fragility" of the arctic environment. It needs to be stressed that vegetated areas should not be trampled, hiking should be conducted on the existing trail and if possible designated campgrounds should be used.

The major concern regarding visitor use is the deterioration of trail conditions. From 1977 to 1984 there was an average of 468 visitors per year of whom 285 visited from June to September and thus hiked rather than skied. Only 5% of these 285 visitors traversed the Pass from north to south, the remainder entered and left from the south end (Welch and Churchill, 1986) unpublished). Impacts on the trail include loss of plant cover, erosion, thermokarst, and the creation of eyesores. Each year it is necessary to repair the trail. It is recommended that in certain sensitive areas, different trail corridors be established so that the visitor impact will be spread over a larger area and thus decrease trail depth. It is the depth of the trail corridor that leads to the most erosion and irreparable damage. In addition, it may be necessary to limit the number of visitors in the park at one time since the present facilities can only handle a certain amount of use.

In the hope of reducing visitor disturbance in the peak summer months, ANPR is trying to promote cross-country skiing in the spring months. Another hazard presents itself at this time of year because female polar bears are leaving their maternity dens with their cubs. The presence of polar bears is a hazard to public safety and the presence of humans is a disturbance to the bears.

Inuit interests

The Inuit want to participate in the management and operation of the park. Every effort is made to employ the local people of Pangnirtung and Broughton Island. Out of the eight full time positions offered at ANPR, six are occupied by Inuit. Also, the five seasonal employees are Inuit. In addition, contracts are given out to the local people for trail repair, garbage and sewage removal and development projects.

However, the Inuit wardens have no opportunity to advance in the park hierarchy because of their lack of scientific training. It is very expensive to send Inuit employees to the South to receive the proper education and training. Consequently the "southern" job descriptions in the park organization are not appropriate in northern parks. Parks Canada has two choices: it can either bring more trained personnel from the South or it can change its objectives in northern parks to better fit the Inuit needs.

The primary interest of the Inuit as regards park operation is the continual management of renewable resource harvesting. The 1979 National Parks Policy states the intent of Parks Canada to involve the Inuit in various aspects of park management;

> 1:3:13 Where new national parks are established in conjunction with the settlement of land claims of native people, an agreement will be negotiated between Parks Canada and representatives of local native committees prior to the formal establishment of the national park creating a joint management regime for the planning and management of the National Park.

Since ANPR is still a reserve and land claims have not been resolved in the Eastern Arctic, joint management does not exist. However, the park has been established for fourteen years and Inuit participation is confined to local advisory committees that were established in the two communities in 1983. The purpose of these committees is to advise the Superintendent on different aspects of park management and development. Since the committees only meet with the Superintendent once a year there is not much input.

Presently, Parks Canada has a good relationship with both communities but this can largely be attributed to the absence of contentious issues rather than a good organizational structure.

Alternatives to National Parks

It seems very difficult for Parks Canada to balance the different interests of preservation, visitor use and Inuit participation. It is argued that Parks Canada has fulfilled its recreation and education mandate by providing four park/reserves North of 60. Conservation in the North requires that large areas of land be set aside for preservation purposes and not for the enjoyment of people. It is important to examine what other conservation alternatives are available and to assess their appropriateness for protecting the northern environment.

Existing legislation

National Wildlife Areas

Wildlife areas may be established by the Minister of the Environment under Section 4. of the *Canada Wildlife Act* (1973):

> Where the Governor in Council (Cabinet) is satisfied that any public lands are required for wildlife research, conservation or interpretation, he may assign the administration, management and control of such lands to the Minister of the Environment.

Therefore, the focus of these areas is intended to be scientific investigation and not visitation. Wildlife areas would be regulated against sport hunting and a general prohibition against the use of vehicles, camping, commercial and industrial activity would be enforced. Since the legislation has not been tested in the North (Polar Bear Pass on Bathurst Island, a "designated" national wildlife area has been fighting for recognition since 1975) it is unclear whether subsistence activities by the local people would be allowed.

Territorial Reserves and Parks

Both the Yukon and Northwest Territories have legislation for creating wildlife reserves and territorial parks. However, in territorial sanctuaries and reserves only sport hunting and fishing is prohibited. Activities like logging, agriculture, oil and gas, and mineral exploration are allowed (Fenge, 1982). In addition, territorial parks are generally for recreation purposes and not for the preservation of the natural environment. Therefore, territorial legislation as it now stands is not preservation oriented. It should be noted that it is very difficult for the territorial governments to establish conservation areas because the federal government owns the majority of the land.

New legislation

Although legislation (both federal and territorial) for protection of the environment exists, they have not been used to their full potential. Little progress has been made in creating wildlife areas or large territorial parks. Two alternatives are proposed:

Wilderness Parks

Parks Canada could create "wilderness parks" and not national parks North of 60. The idea of creating wilderness parks was first put forward by Mr. Justice Berger in the Mackenzie Valley Pipeline Inquiry. Berger argued that the existing *National Parks Act* did not adequately protect the northern wilderness:

> Our national park legislation, as it now stands, is not adequate to preserve northern wilderness areas, which, if they are to be preserved, must be withdrawn from any form of development. That principle must not be compromised. It is essential to the concept of wilderness itself as an area untrammeled by industrial man (Berger, 1979)

Wilderness parks could easily be created by amending the *National Parks Act* to legalize zoning and management plans. Therefore, a park could be zoned as wilderness and no facility development would be allowed. This amendment is presently under consideration by the Department of the Environment.

Ecological Reserves

Alternatively, ecological reserves could be created North of 60. Revel (1981) argues that an Ecological Reserves Act is needed in Northern Canada. Revel concedes that the present federal and territorial legislation are relevant to the protection of ecological sites, but argues that their purposes are directed predominantly to the management of a few ecosystem components. Presently, there is not one piece of legislation that ensures the protection of the ecosystems and their components collectively. For example, in order to protect migratory species, not only do critical sites need protection, but surrounding areas must also be protected as buffers against development interests.

Therefore, "from both the legislative and the ecological standpoints, what appears to be necessary is a legislative mechanism (Ecological Reserves Act) which provides authority to manage ecosystems as a whole, allows for the development and implementation of site specific management plans and ensures the long-term existence of the ecological sites independent of goodwill on behalf of the Minister authorized to administer that specific piece of legislation" (Revel, 1981).

Conclusion

More national parks North of 60 is not the answer to the northern conservation problem. First, many areas in the North are too sensitive to visitor impact and thus the public use mandate of Parks Canada is inappropriate. Second, Inuit participation in the management of conservation areas needs to be increased and this can not be accomplished under the present park structure. And finally, the costs of operating a northern national park are proving too high to justify Parks Canada as being the premier conservation agency in the North. The northern wilderness needs to be protected in an efficient and comprehensive manner and it needs to be protected before it is too late.

References

Berger, Thomas. 1977. Northern Homeland, Northern Frontier. Ottawa: Supply and Services.

Department of the Environment. 1983. Environment Canada and the North: The Perceptions, Roles, and Policies of the DOE regarding Development North of 60. Ottawa.

Department of Indian Affairs and Northern Development. 1979. Parks Canada Policy. Ottawa.

Fenge, Terry. 1982. "Towards Comprehensive Conservation of Environmentally Significant Areas in the Northwest Territories of Canada". Environmental Conservation. Vol. 9 No. 4.

Lawrence, R.D. 1983. Canada's National Parks. Toronto: Collins.

Nelson, J.G.; Smith, P.G. and J.B. Theberge. 1984. ESA's in the NWT Canada: Their Role, Identification, Designation and Implementation. Ottawa: Canadian Arctic Resources Committee.
Parks Canada. September, 1982. Auyuittuq National Park Reserve: Interim Management Guidelines. Ottawa: Parks Canada.
Tennent, Caroline. 1980. "Inuit Response to Proposed Northern Parks" Park News (Winter).
Theberge, John B. 1983. "The North — Vulnerable or Resilient?" Park News Vol. 19, No. 2.
Revel, Richard D. 1981. "Conservation in Northern Canada: International Biological Programme Conservation Sites Revisited" Biological Conservation. 21:263-287.

Legislation

National Parks Act (1930) ch.N-13, R.S.1930c.
National Park Amendment Act S.C. 1974 c.11 s.11.
Canada Wildlife Act S.C. 1973 c.21.

QUANTITATIVE VEGETATION ANALYSIS, SOUTHERN BAFFIN ISLAND — PHASE ONE: IQALUIT AREA

Lin Maus
Department of Geography, University of Windsor, Windsor, Ontario N9B 3P4

Level: Master's

Abstract

Bioclimatic zones in the Arctic are based on simple plant-climate relationships and limited information about actual plant distributions whereas in fact, plant community structure is greatly altered by variation in microhabitat within this region. In order to gain a better understanding of the degree to which vegetation and microhabitat factors vary at similar sites in the Low Arctic, a quantitative vegetation analysis with respect to environmental factors was conducted across southern Baffin Island's Low Arctic zone between 1984 and 1986. Within this period 20 transect lines, 50 meters in length, for a total of 205 half-meter grid points were analyzed for plant species, microhabitat and soil chemistry. In the first phase of the project five locations in the Iqaluit area were sampled. The results of the analysis indicated a tendency for plant community structure to vary across transect lines but not between lines at similar sites. Associations were demonstrated between plant species and environmental factors. Analysis of the 1985 and 1986 data which covered the latitudinal extent of this region may elicit a better understanding of plant community structure with respect to environmental factors on a local scale and help clarify these relationships on a regional scale. A better understanding of these plant community and environmental associations may assist in the more accurate delineation of bioclimate zones in the Low Arctic on southern Baffin Island.

Key words: Southern Baffin Island, plant community composition, microhabitat.

Résumé

La délimitation des zones bioclimatiques de l'Arctique se base souvent sur des relations supposément simples entre les végétaux et le climat et sur des renseignements peu nombreux au sujet de la répartition réelle des plantes. Même au sein d'une seule région, à laquelle la carte climatique peu détaillée attribue des conditions uniformes, il existe toute une gamme d'habitats locaux et de microhabitats favorisant la diversité des peuplements végétaux. L'auteure s'efforce d'évaluer l'ampleur de la variation végétale et des facteurs de microhabitat dans des lieux similaires de l'Arctique méridional dans le sud de l'île de Baffin.

L'auteure a effectué des recherches sur la composition des peuplements végétaux, la topographie, le microclimat et la composition chimique des sols dans ses lieux d'aspects, de pente et d'altitudes similaires, aux alentours de Lake Harbour, Pangnirtung, Frobisher Bay, et au lac Nettilling. L'abondance des espèces végétales et leur diversité ont été quantifiées par échantillonnage au hasard, au long de bandes de 50 m, à l'aide d'une grille. Les échantillons de sols prélevés ont été ensuite analysés pour déterminer leur teneur en eau, leur structure, leur teneur en matières organiques, Ca, P,Mg, et leur pH.

L'auteure a établi des corrélations entre la végétation et les paramètres de microhabitat, et utilisé l'analyse de ces principaux éléments pour déterminer les traits généraux de la covariation spatiale de la répartition des espèces et des facteurs d'environnement. Les conclusions préliminaires indiquent que, dans des conditions topographiques similaires, c'est la composition des sols qui explique le mieux la diversité et l'abondance des peuplements.

Mots-clés: Sud de l'île de Baffin, composition du peuplement végétal, microhabitat.

Introduction

The delineation of bioclimatic zones in the Arctic often proceeds from simple plant-climate relationships (e.g. Young, 1971) and limited information about actual plant distributions. Even within a region where coarse regional climatic maps suggest uniform conditions, a wide range of local- and micro-habitats find expression in a variety of plant communities. The structure of these plant communities is determined by microhabitat conditions which meet the requirements or tolerance for water, light, and soil of more than one plant species. In the Arctic, especially favourable microhabitats can produce diverse and dense vegetation close to areas of relatively sparse cover. While snowcover plays an important role in site favourability by providing

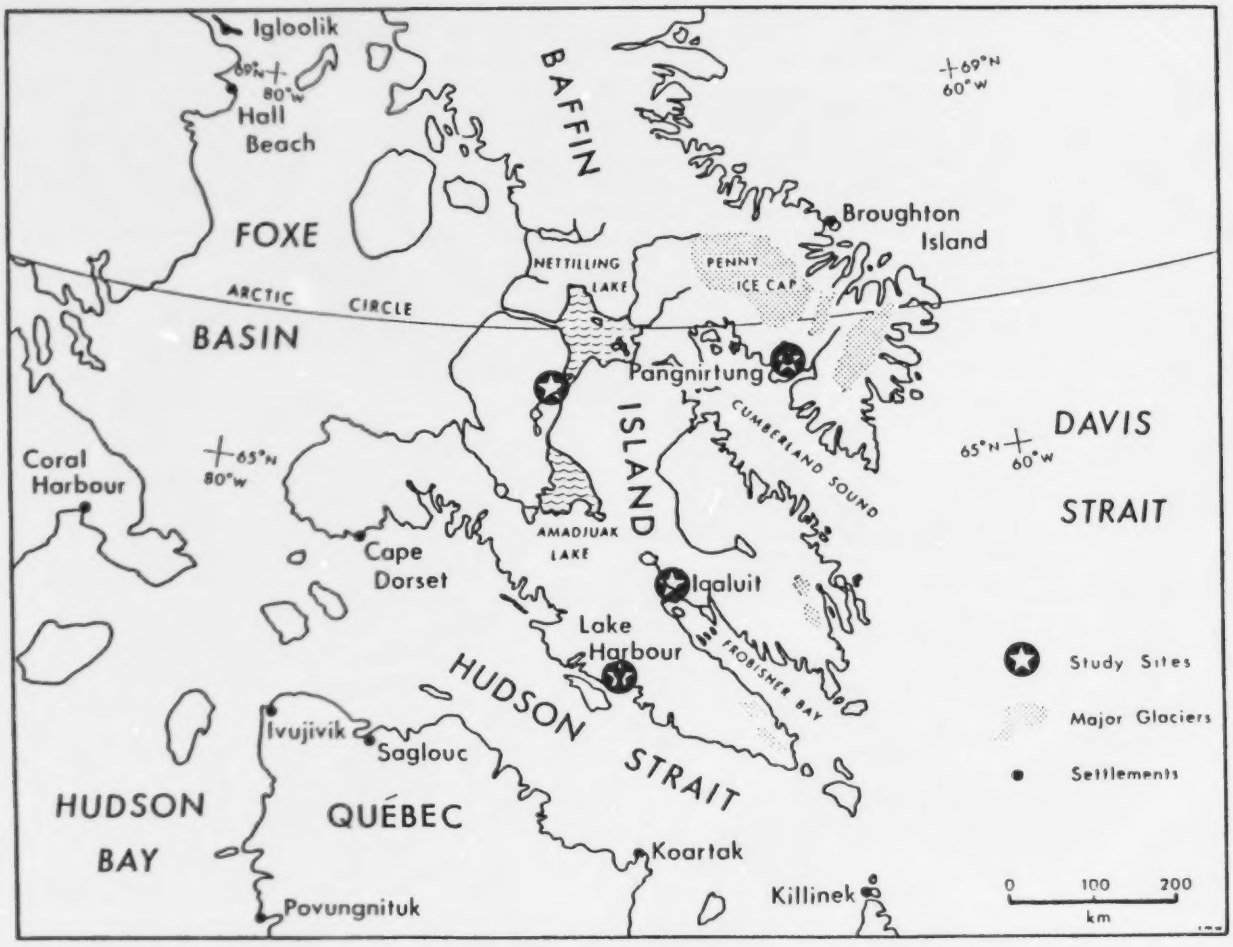


Figure 1. Study area locations within the Low Arctic Region, southern Baffin Island.

insulation in winter and water in summer, it also shortens the growing season and influences soil movement (Helm, 1982). Plant communities often form concentric rings around snowpatches. Drainage patterns and microsite differences can produce complex mosaic patterns (Helm, 1982). Raised beach ridges and frost polygons develop distinctive tundra plant communities (Miller and Alpert, 1984). These small scale differences in plant communities in response to slight variations in topography make the Arctic an ideal place to study the edaphic and microclimatic control of vegetation (Miller and Alpert, 1984).

Gradient analysis of vegetation can be utilized to determine the relationship between the kinds of vegetation and their topographic position in the landscape (Whittaker, 1967). The structure and variation of vegetation along a transect is analyzed based on the environmental factors, species populations and community characteristics. Quantitative vegetation analysis at several sites within a single bioclimatic zone would assist in determining the effect of environmental controls on plant community structure within that region.

Southern Baffin Island has been consistently classified bioclimatically as a Low Arctic zone (e.g. Porsild, 1958). The Low Arctic is generally considered to have a good cover of low-growing shrubs such as birches and willows as well as dense sedge meadows at wet sites. The productivity of the Low Arctic zone has been estimated at 250 to 500 g m-2 yr-1 (Lieth, cited in Webber, 1974). While the term Low Arctic is taken to mean that the plant communities should be relatively homogeneous across this region where site conditions are similiar, it is to be expected that there will be changes in tundra types (plant associations, life-forms and species diversity) with latitude and altitude (Wielgolaski, 1981).

This study is aimed at determining the extent to which vegetation and microhabitat factors vary at similar sites across the Low Arctic region of southern Baffin Island. For this purpose, a program of vegetation and microhabitat analysis was undertaken at four, apparently environmentally similar, locations across the approximately five degree latitudinal extent of this zone.

Methodology

In three consecutive field seasons, sites near the settlements of Iqaluit (Frobisher Bay), Pangnirtung, Lake Harbour and

on Nettilling Lake (Fig. 1) were sampled using the grid and transect method. A forest-tundra ecotone was sampled at 58 N latitude near Kuujjuaq, in Northern Quebec. It was included in the study to provide information on mainland Low Arctic plant community structure.

At all locations, study sites were selected which were alike in terms of slope, elevation, and aspect. Transects were located on gradual (5–10 degree) south to southwest facing slopes less than 100 m above sea level. Each started at a ridge crest and ran downslope. At each site a 50 meter long transect line was divided into 5 m intervals. Sample data were collected using a half meter grid. (Fig. 2) placed randomly within each interval. A plastic sheet placed over the grid was used to record plants present in each two centimeter cell. Voucher specimens were collected for verification.

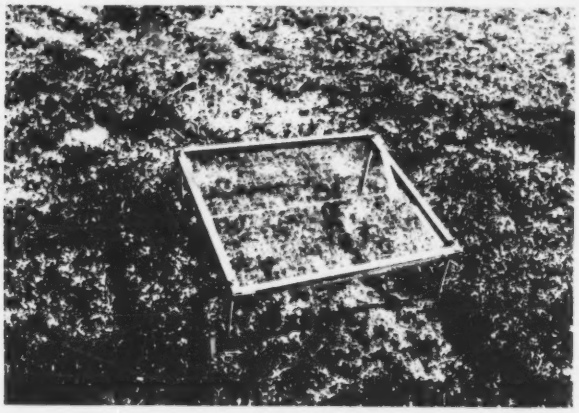


Figure 2. Half meter plexi-glass grid divided in 2 cm squares utilized for vegetation analysis.

At each grid location the following environmental data were also taken: air temperature and relative humidity at 1.5 m above ground, temperature of the canopy, at the surface, and soil temperature at 5, 10, 15 cm depth. Soil pH and soil moisture were measured in the field. Soil samples were packaged and returned to the laboratory for evaluation of texture, and organic, magnesium, potassium and phosphorous content.

This report is concerned with the results of the first phase of the study which was intended to determine the extent of variance of community structure among different sites at the same Low Arctic location. The hypothesis to be tested was that, while there may be variation within sites as a result of microhabitat differences, there will be no significant difference in community structure between similar sites within the same locale.

The initial phase of the analysis included five sites (Apex 1, Apex 2, Tarr Inlet, West Sylvia Grinnell, and East Sylvia Grinnell) sampled in 1984 near the settlement of Iqaluit. At each of five sites, species occurrences in 11 grids were recorded, each grid recording the species present in 625 squares. Analysis of the grid data involved species counts which were used to calculate dominance and diversity. Dominance is defined by Simpson's Index of Dominance (SID) which is an index between zero and one. A high index indicates a few species have contributed a large proportion to the total cover. Or,

$$SID = \sum_i P_i^2$$

where P = proportion of individuals of species *i* in the community. Diversity, calculated by the Shannon-Wiener Diversity Index (SWDI) given by:

$$SDI = \sum_i^s p_i \log_2 p_i$$

where s = number of species, and p proportion of total sample belonging to the *i*th species (Krebs, 1978).

Differences in dominance between grids and along the transect were determined using Student's t-test and differences between communities were tested by ANOVA. Principal components analysis was used to test for covariation among species and environmental factors within the study area.

TABLE 1
Results for two-tailed Student's t Test computed on grid and transects

Results for two-tailed Student's t test computed on grid and transects

LINE	NUMBER OF GRIDS	
	S	NS
APEX LINE 1	8	3
APEX LINE 2	6	5
TARR INLET	7	4
WEST SYLVIA GRINNELL	2	9
EAST SYLVIA GRINNELL	4	7

T-crit = 2.228 based on 95% confidence level with 10 degrees of freedom
S= significant - t-observed is greater than t-crit
NS= not significant - t-observed is less than t-crit

Results

Although there is evidence that dominance is not always closely tied to diversity (Krebs, 1978), the 1984 Iqaluit data, when analyzed for species dominance and diversity, showed that dominance was in fact inversely related to diversity, therefore analysis was continued using only dominance values. Using 95% confidence intervals the dominance indices of 27 of the 55 grids surveyed were significantly different from their respective transect means (Table 1). This indicates that there is significant variation in the plant communities along the transect line.

ANOVA demonstrated that, of the five lines analyzed, four were statistically indistinguishable from the population mean (Table 2). This would tend to support the hypothesis that the communities sampled within this region were basically similar. The community which differed significantly from the population mean in the ANOVA had only two grids

TABLE 2
F-ratios obtained from ANOVA using community dominance values when testing for differences between transects

LINE	F-RATIO
APEX LINE 1	3.979
APEX LINE 2	0.516
TARR INLET	1.208
WEST SYLVIA GRINNELL	7.857*
EAST SYLVIA GRINNELL	0.291

F-critical = 4.08 at the 95% confidence level with the degrees of freedom 1, 53

* F-observed exceeds F-critical

TABLE 3
Principal components (one and two) eigenvalues and eigenvectors obtained using environmental factors and plant species

Component	Eigenvalue	Proportion	Cumulative
1	5.260	0.150	0.150
2	3.764	0.108	0.258

Principal Component 1

Name	Eigenvector	Squared Loadings
Diversity	+.352	.124
Dryas integrifolia	+.300	.090
Cassiope tetragona	+.273	.075
Texture	+.267	.069
Evenness (sample)	+.261	.069
pH (field)	+.260	.068
In canopy temperature	+.250	.062
% organic content	+.220	.048
Salix reticulata	+.201	.040
Dominance	-.340	.115
lichen	-.225	.050

Principal Component 2

Name	Eigenvector	Squared Loadings
Magnesium	+.390	.152
Potassium	+.358	.128
% organic content	+.316	.100
Phosphorous	+.260	.067
Arctostaphylos alpina	+.233	.054
Texture	+.218	.048
Leaf Litter	+.217	.047
pH (field)	-.250	.062
Air temp - soil 5 cm	-.210	.044

which varied from their transect mean, suggesting a uniform community structure along the transect line. This last site is separated from the other sites by the Sylvia Grinnell River which may be a phytogeographic boundary (Jacobs *et al.* 1985).

Principal components analysis showed that although an association exists between species composition and environmental factors, the ability of the analysis to explain community structure with respect to environmental factors is low. The first principal component has a lower eigenvalue than would be necessary to show conclusive relationships, although the results suggest that expected plant — environment relationships exist (Table 3). For example, the first component emphasized the association among *Dryas*, *Cassiope* and *Salix*, combined with temperature, pH and organic content of the soil. The implication is that these environmental components are relatively important in the *Dryas* — *Cassiope* — *Salix* community association. The second component includes only one plant species, *Arctostaphylos alpina* in relationship to soil composition (magnesium, potassium, organic content, phosphorous, texture and leaf litter) (Table 3). These components explain only 26% of the covariation in the species and environmental factors. The addition of 150 grids in the continuing analysis should reduce the random variation between sites and clarify these initial findings.

Conclusion

In the Low Arctic bioclimatic zone on southern Baffin Island, a total of 20 transect lines with 205 grid points were analyzed for plant species and environmental factors from 1984 to 1986. The first phase of the project involved the analysis of data collected on the transects in the Iqaluit area. The results showed a tendency for the plant community structure to vary across the transect line but to be basically similar between transects. Associations were suggested between community structure and environmental factors. An additional 150 grids collected in 1985 and 1986 will be analyzed to clarify the patterns that emerged from the initial findings. The sites collected between 1985 and 1986 covered the approximate five degree latitudinal extent of this zone and therefore will not only add strength to the additional findings, but will also help describe the variation in plant community structure across this latitudinal gradient with respect to environmental factors.

An understanding of plant community structure based on environmental factors enables not only a more accurate classification of present day vegetation and climate boundaries to be made, but also allows for a more precise interpretation of paleobotanical samples and paleoclimates (Edlund, 1983). At present, the existing boundaries are based on simple plant-climate relationships. A standard, easily reproduced method for data collection is needed for the formation of a data base to be used to determine the extent to which vegetation and environmental factors vary across the Low Arctic.

Acknowledgments

The environmental data includes microclimate readings and soil samples collected by J. Gillies, V. Bingham (1984), S. Tracey, G. Greenwood (1985), C. Clarke, and L. Chandler (1986). Soil samples were analyzed courtesy of Agri-Food Laboratories, Guelph, Ontario. J.D. Jacobs and I.M. Weis read and commented on the manuscript. Funding for this research has been provided by the Natural Sciences and Engineering Research Council of Canada (undergraduate and graduate research awards) and the Department of Indian and Northern Affairs Northern Scientific Training Grants.

References

Edlund, S.A. 1983. Bioclimatic zonation in a High Arctic region: central Queen Elizabeth Islands. In: Current Research, Part A, Geological Survey of Canada, Paper 83-1A:381-390.

Helm, D. 1982. Multivariate analysis of alpine snowpatch vegetation cover near Milner Pass, Rocky Mountain National Park, Colorado, U.S.A. Arctic and Alpine Research 14(2):33-42.

Jacobs, J.D., Mode, W.N., and Dowdeswell, E.K. 1985. Contemporary pollen deposition and the distribution of *Betula glandulosa* at the limit of Low Arctic Tundra in Southern Baffin Island, N.W.T., Canada. Arctic and Alpine Research 17(3):279-287.

Krebs, C.J. 1978. Ecology: the experimental analysis of distribution and abundance. 2nd ed. New York: Harper and Row Publishers.

Miller, N.G., and Alpert, P. 1984. Plant associations and edaphic features of a High Arctic mesotrophic setting. Arctic and Alpine Research 16(1):11-24.

Porsild, A.E. 1958. Geographical distribution of some elements in the flora of Canada. Geographical Bulletin 11:57-77.

Webber, P.J. 1974. Primary productivity. In: Ives, J.D. and Barry, R., eds. Arctic and Alpine Environments. London, Metheun & Co. Ltd. 445-475.

Whittaker, R.H. 1967. Gradient analysis of vegetation. Biological Review. 49:207-264.

Wielgolaski, F.E. 1981. Vegetation types and primary production in tundra. In: Wielgolaksi, F.E. and Rosswall, T., ed. I.B.P. Tundra Biome. Proceedings IV International Meeting Leningrad. Stockholm.

Young, S.B. 1971. The vascular flora of St. Lawrence Island with special reference to floristic zonation in the Arctic region. In: Rollins, R.C., and Rudenberg, L., ed. Contributions from the Gray Herbarium. Number 201. The Gray Herbarium of Harvard University.

EARLY TERTIARY FOSSIL CEDARS OF THE CANADIAN HIGH ARCTIC

E.E. McIver and J.F. Basinger

Department of Geological Sciences, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0

Level: E.E. McIver, Ph.D.

Abstract

Recent collections of plant megafossils from Ellesmere and Axel Heiberg islands are contributing to our understanding of early Tertiary floras of northern Canada. Of particular interest is the recovery of remains, both leafy branches and seed cones, of cedars from 60 million year old sediments of Ellesmere Island. Since taxonomy of modern conifers is based primarily upon reproductive features, the discovery of seed cones is significant. Fossil foliage and cones of the cedar resemble most closely those of *Thuja plicata*, the western red cedar of the Pacific coast. Unlike present vegetation of Canada, with arctic through temperate zonation, early Tertiary vegetation appears to represent a more cosmopolitan temperate geoflora. Extensive forests of *Metasequoia* (dawn redwood), *Glyptostrobus* (swamp cypress), *Cercidiphyllum* (katsura), and birch? covered much of Canada from the southern border to Ellesmere Island. In addition to these four nearly ubiquitous taxa, our collections reveal associated forms including ferns and members of the sycamore, walnut, oak, linden, and other families. Continuing work on the fossil plants of northern Canada is increasing our appreciation of diversity and distribution of early temperate floras, and helps us to understand the origin and evolution of the modern floras of Canada.

Key words: Fossil cedar, Early Tertiary, High Arctic, *Thuja*, paleobotany.

Résumé

Les grands végétaux fossiles recueillis récemment dans les îles d'Ellesmere et d'Axel Heiberg élargissent nos connaissances sur les flores du début du Tertiaire dans le Nord canadien. La découverte de branches feuillues et de cônes porte-graines de cèdre dans des sédiments de ~60 Ma dans l'île d'Ellesmere présente un intérêt particulier. Comme la classification taxonomique des conifères actuels est surtout fondée sur les caractéristiques des organes reproducteurs, cette découverte de cônes porte-graines est importante. Le feuillage fossile et les cônes de ce cèdre ressemblent étroitement à ceux du *Thuja plicata*, le «cèdre rouge» du littoral pacifique. Contrairement à l'actuelle végétation des zones arctique à tempérée, celle du Tertiaire inférieur semble constituer une flore tempérée plus cosmopolite. De vastes forêts de *Metasequoia*, de *Glyptostrobus*, de *Cercidiphyllum* et de bouleau? couvraient la plus grande partie du Canada, de sa limite méridionale à l'île d'Ellesmere. Outre ces quatre taxons presque ubiquitaires, les spécimens recueillis par l'auteure montrent des formes associées, y compris des membres des familles du sycomore, du noyer, du bouleau, du chêne, du tilleul et d'autres. La poursuite des travaux sur les végétaux fossiles du Nord canadien nous fait mieux saisir la diversité et la répartition des flores anciennes des régions tempérées, et nous aide à comprendre l'origine et l'évolution de la flore actuelle du Canada.

Mots-clés: Fossile, flore du Tertiaire inférieur, île d'Ellesmere, *Thuja*, paléobotanique.

Introduction

Cedar remains are not uncommon in Tertiary fossil assemblages in the Arctic (Heer, 1870, 1878, 1882, 1883; Schweitzer, 1974; Magnum, 1962; Sveshnikova and Budantsew, 1969) and mid-latitude floras (Bell, 1949; Berry, 1935; Brown, 1962; Newberry, 1886), yet our knowledge of cedar evolution is severely limited. The fossil foliage of these early cedars often resembles modern taxa and is on this basis often assigned to modern genera. This practice has frequently led to incorrect assignment, since identification of conifers is based principally on seed cone structure (Li, 1953). Our recent collections of plant fossils from Ellesmere Island include cedar material, both vegetative and fertile. This fossil cedar is a significant find since it allows us to accurately identify an Early Tertiary cedar not previously known, and provides valuable data for our current study of cedar evolution.

A serious handicap to the investigation of Canadian past and present floras is the insufficiency of fossil evidence. As a result, interpretations of origins and evolution in these temperate floras is largely speculative. In addition, researchers have long assumed that diversity in the Canadian Early Tertiary floras was low in the high-latitudes and increased towards the south, but the nature of the floristic latitudinal differences has never been thoroughly documented. Our present collections are revealing that diversity in the north

was greater than previously thought, although less diverse perhaps than mid or low-latitude floras. Furthermore, in theory great mesophytic forests covered most of the Northern Hemisphere during the Early Tertiary (Li, 1952), a premise supported by the fossil record of the mid-latitudes, Alaska, Greenland, and Spitzbergen (Wolfe, 1969; Berry, 1930). However, apart from our arctic collections, there has been little fossil evidence from the Canadian North to document the geographical extent of these floras in Canada. A few notable data sources include brief reports by Dawson (1889) and Heer (1868) on floras of the Mackenzie Valley and Ellesmere Island, and preliminary accounts of High Arctic floras by Hickey (1984).

Our recently acquired plant fossil collection is allowing new insight on the distribution, diversity, and origins of high-latitude vegetation and provides the basis for our continuing study of evolution within Canadian floras.

Materials and Methods

The fossils used in this study were collected over the past two years from Axel Heiberg and Ellesmere Island in the Canadian Arctic. Most of the plant remains are compressions preserved in sandstone, siltstone, mudstone, or rarely shale.

Fossil material, including the cedar remains, occur in sediments of the Iceberg Bay Formation of the Eureka Sound Group. The Eureka Sound Group, formerly the Eureka Sound Formation, has been recently redefined by Miall (1986) and Ricketts (1986). Ricketts, on the basis of detailed examination of stratigraphy, structure, and palynology, divides the Group into four new lithologically distinct formations: the Expedition Formation (Campanian to middle Paleocene); the Strand Bay Formation (early to middle Paleocene); the Iceberg Bay Formation (middle or late Paleocene to middle Eocene); and the Buchanan Lake Formation (middle to late Eocene).

The Eureka Sound Group underlies large tracts of the Arctic Archipelago, especially in the eastern Arctic. There are major outcroppings of the Group along the eastern Sverdrup Basin, and minor occurrences scattered over much of the arctic islands (Ricketts and Embry, 1984). The Strand Bay and Iceberg Bay Formations are in places rich in coal seams, indicating that during the Late Cretaceous and Early Tertiary, plant remains were accumulating in a number of smaller sub-basins (Miall, 1986).

The Iceberg Bay Formation is characterized by three lithotypes: a basically non-calcareous sandstone and shale; a calcareous siltstone and sandstone; and a sandstone and coal unit (Ricketts, 1986). Plant fossils occur in the coal-bearing sandstone unit where fining-upward sandstone-coal cycles predominate. The depositional environment is interpreted as primarily fluvial, with barrier islands, lagoons, shelf deposits, and delta plains included. Plant fossils from the Iceberg Bay Formation include *Metasequoia*, *Glyptostrobus*, *Cercidiphyllum*, *Ginkgo*, and members of the birch, oak, sycamore, linden, walnut, cedar, and other families. Our collections were obtained from sediments near the base of the Formation and are dated as Paleocene, probably middle Paleocene (Ricketts pers. comm.).

The cedar remains, vegetative and fertile, were collected from sediments cropping out on a stream bank about 20 km east of Eureka on Ellesmere Island. The amount of excavation that could be carried out to obtain adequate material was limited to a depth of about 30 cm by permafrost. In addition, frost action on the fine-grained fossiliferous mudstone produces highly friable and fragmented pieces, making it difficult to recover large specimens. Our collection consists of 60 specimens of vegetative material and three of seed cones.

Description

The foliage of the fossil cedar from Ellesmere Island is characterized by an alternate branching pattern and flattened branchlets. The branches are highly divided and arise in the axils of branch lateral leaves. The branchlets are slender and occasionally overlap due to the frequency of branching along one side of the axis (Fig. 1).

The leaves are small, decussate, and scale-like. The facial leaves are closely adpressed and apparently without resin glands. Branchlet (short shoot) facial leaves are ovate with an acute tip, and are distinctly thickened near the apex. Branch (long shoot) facial leaves are linear to oblong with an acute or obtuse apex.

Branch and branchlet lateral leaves are folded along the midline. Branchlet lateral leaves have an acute apex which is rarely free, and are closely adpressed to the succeeding facial leaf. Branch lateral leaves have free tips, are decurrent and falcate, and partially overlap the succeeding facial leaf.

Seed cones are attached to a leafy, reflexed axis (Fig. 3). The cones appear oblong to elliptic and are up to 10.0 mm long and 6.0 mm wide. There are 8–9 pairs of cone scales which appear thin, woody or leathery, and bear a distinct, reflexed umbo near the apex. The innermost pair of scales appears to be rudimentary, forming a columella-like structure (Fig. 5). Seeds and pollen cones are not known.

Discussion

The family Cupressaceae, which includes about 20 genera and 135 species, is broadly distributed over both hemispheres. All genera of the family have a whorled or decussate phyllotaxy, and most bear scale-like leaves. Although some genera may be distinguished from others on the basis of foliage, many cannot. Therefore, classification at the generic level is based primarily on seed cone structure.

The fossil cedar from Ellesmere Island bears the decussate, scale-like leaves characteristic of cupressaceous foliage. The leafy branches of the fossil appear most similar to those of *Thuja*, with alternate branching, finely divided sprays and flattened branchlets. Since other genera of the Cupressaceae, such as *Chamaecyparis*, and *Heyderia*, may bear foliage which closely resembles that of *Thuja* (Dalimore and Jackson 1966), assignment of cedar material to *Thuja* is more correctly based on seed cone structure.

Thuja can be easily distinguished from other Cupressaceae genera by its combination of cone scale characteristics. The seed cones of *Thuja* bear at least four pairs of thin, leathery to somewhat woody scales with small umbos; two or three of these pairs of scales are the same size, and all are imbricate. The fossil cedar cones bear 8–9 pairs of thin,

Figure 1. Leafy branch of fossil cedar, Ellesmere Island, showing branch and branchlet leaves. × 3.

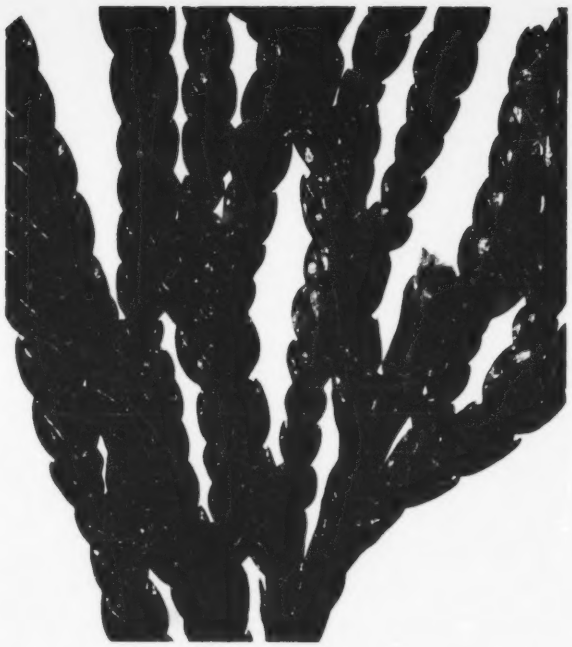


Figure 2. Leafy branch of *Thuja plicata* showing branch and branchlet leaves. × 4.

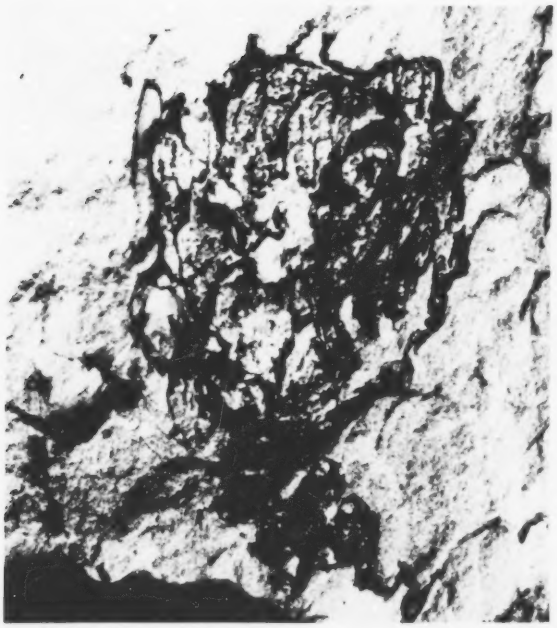


Figure 3. Seed cone of fossil cedar, Ellesmere Island. Note attached leafy axis. × 9.

Figure 4. Seed cone of *Thuja plicata* showing attached leafy axis. × 6.

Figure 5. Seed cones of fossil cedar, Ellesmere Island. Note rudimentary inner most scales forming a columella-like structure. × 6.

Figure 6. Dissected cone of *Thuja plicata*. Note decussately arranged scales and rudimentary innermost scales. × 5.

imbricate scales with small umbos; most scales appear similar in size. The fossil cones are unlike those of other Cupressaceae genera except *Thuja*, including those with similar foliage, *Chamaecyparis* and *Heyderia*. The seed cones of *Chamaecyparis* are globose and bear peltate, woody scales with prominant reflexed umbos; cones of *Heyderia* bear two pairs of very unequal woody scales.

Extant *Thuja* inhabits moist, often nutrient poor or coastal areas in the Northern Hemisphere. Of five living species, *Thuja koraiensis*, *T. standishii*, and *T. sutchuenensis* occur in eastern Asia; two, *T. occidentalis* and *T. plicata* are native to North America. *Thuja occidentalis* is widely distributed in eastern North America, often restricted to swampy ground or saturated soils. *Thuja plicata* grows in the moist, coastal and montane forest regions of the Pacific coast.

The leaf and seed cone structure of the fossil cedar appears most similar to *Thuja plicata* (Figs. 2, 4). However, the seed cones of *T. plicata* differ little from those of *T. occidentalis* except that the former exceed the latter in size. Nevertheless, leaves of *T. occidentalis* are dissimilar to leaves of both *T. plicata* and the fossil in two distinctive characteristics. Firstly, the lateral leaves of *T. occidentalis* bear obvious resin glands near the apex, which are not apparent on the fossil leaves and are inconspicuous on leaves of *T. plicata*. Secondly, *T. occidentalis* foliage is more flattened and much more highly branched, with repeated overlapping of branchlets, a characteristic not found in the other two taxa.

The Asian species of *Thuja* differ from the Ellesmere Island cedar in the same characteristics by which they can be distinguished from *T. plicata*. *Thuja sutchuenensis* bears smaller cones (up to 6 mm long) with tightly overlapping scales. The scale apex is scarcely free and only slightly thickened. The facial leaves are distinctly grooved, a characteristic not found in the other four species or the fossil.

Thuja standishii differs from the other species on the basis of the coarse, thickened branchlets which it bears, and in its seed cone shape which is broadly ovate. *T. koraiensis*, in contrast, bears branchlets which are extremely flattened, concave or grooved below, and distinctly glandular. The cones of *T. koraiensis* are more elliptic in shape and bear only four pairs of scales.

The cone scales of *Thuja plicata* are thin, leathery, and imbricate, with small umbos on the apophyses. The first pair of scales are sterile and slightly smaller than the fertile second and third pairs. The fourth pair are also smaller but usually fertile. Scales of the fossil cones appear thin, leathery, and imbricate, with distinct umbos near the apex, and the middle pairs of scales appear largest. In both *T. plicata* and the fossil the innermost pair of scales are rudimentary, forming a columella-like structure (Figs. 3, 6).

Despite the remarkable similarity between cones of the fossil and *Thuja plicata*, they differ on one significant character — the number of cone scales.

Thuja-like fossils have been reported from numerous localities throughout the Northern Hemisphere from the Jurassic to the end of the Tertiary, indicating that cedars have a long

history and were once more widespread than today (Florin, 1963). Most of these fossil remains consist of vegetative material only and are best assigned to the form genus *Cupressinocladus* (Schweitzer, 1974). Consequently, the fossil record of *Thuja*, itself, becomes restricted to remains which are fertile; unfortunately reports of *Thuja*-like seed cones in the fossil record are rare.

Schweitzer (1974) assigns Early Tertiary cedar material from Spitzbergen, which includes attached seed cones, to *Thuja ehrenswardi*. *Thuja ehrenswardi* differs from the Ellesmere Island cedar in both seed cone structure and foliage. The cones from Spitzbergen are small (4 mm long) and bear at least four pairs of closely-overlapping, imbricate scales, without obvious umbos. These cones, according to Schweitzer, are very much like those of extant *T. sutchuenensis*. The foliage of *T. ehrenswardi* bears branchlet lateral leaves which are widely spreading distally, the apex free. Branchlet lateral leaves of the Ellesmere Island cedar are closely adpressed throughout their length, including the apex. Both these fossil cedars appear to be *Thuja* but are sufficiently different to require separate specific status.

From Early Tertiary sediments of Greenland, Heer (1874) described and illustrated *Thuja*-like fossil material which includes attached cones. Heer ascribed this material to *Biota borealis*, even though the attached cones do not bear the large reflexed umbo of extant *Biota*. In any case, these cones are quite unlike the cones of either the Ellesmere Island fossil or *Thuja ehrenswardi*.

The only other Early Tertiary *Thuja*-like fossil with associated fertile material we know of is *Thuites corpulentes* from Late Cretaceous sediments of the Nanaimo Group, Vancouver Island (Bell, 1957). The foliage is similar to *Thuja* but the cones Bell attributes to the taxon are unlike any known *Thuja*, extant or fossil. We feel Bell's (1957) material should not be assigned to either *Thuja* or *Thuites*.

More recent sediments from the Late Miocene flora of Akita Prefecture, Japan yield fertile *Thuja* fossils which are very similar to the extant species now inhabiting adjacent territories. Huziola and Vemura (1973) assigned this material to *Thuja nipponeca* on the basis of similarities with *Thuja standishii*.

Many extant Northern Hemispheric genera, including *Thuja*, appear closely related, with numerous overlapping characters. Studies of evolutionary relationships within these taxa are based on seed cone and seed structure to a large extent. The general tendency in regards to evolution within the Cupressaceae, as in all gymnosperms, is towards reduction (Baird, 1953). The generalized ancestor of most Northern Hemispheric (and perhaps some Southern Hemispheric) Cupressaceae is believed to have borne a woody, globular, many-scaled ovuliferous cone and terete (non-flattened) branchlets (Eckenwalder, 1976). Specialized cones would be those with a reduced number of cone scales or fusion of scales or both.

The flattened branchlets and leathery cone scales of the Ellesmere Island cedar indicate that by the Early Tertiary *Thuja* had already evolved a number of specialized characteristics. We have noted the morphological similarity between the fossil and *Thuja plicata* and, consequently, we could speculate that our fossil portrays an ancestor of *T. plicata*. Accordingly, it appears that evolution in *Thuja plicata* has included the reduction in the number of cone scales, since the fossil bears 8–9 pairs of scales and *T. plicata*, 5–6 pairs. Furthermore, the similarity of the Ellesmere Island cedar with *T. plicata*, and the resemblance of *T. ehrenswardi* with *T. sutchuenensis* suggests that, by the Early Tertiary, at least two very distinct species of *Thuja* were present.

The Cenozoic history of North American temperate floras, including the northern Canadian assemblages to which this fossil cedar was associated, appear exceedingly complex (see Graham, 1972). Although a wealth of data are available for the mid-latitudes there has not been general agreement among researchers with regard to the origin of North American temperate floras. As a result, various philosophical explanations have been proposed to link the Early Tertiary floras with the modern. These theories include R.W. Chaney's (1959) classical concept of migrating floristic assemblages (Geofloras) in time and space and J.A. Wolfe's (1969) hypothesis of direct adaptation during climatic changes, with subsequent diversification and evolution in some lineages. Current data, including our recent collections from the High Arctic, and past collections from contemporaneous high-latitude sediments (see Berry 1930) suggest that no one theory is sufficiently inclusive to explain the origins and evolution of these temperate floras.

The parallels between Early Tertiary fossil floras and modern temperate floras appear to involve similarities in vegetation type rather than similarities in floristic assemblages. There are lineages and genera which have persisted over time and perhaps there were southern migrations of some taxa, particularly in the Late Cenozoic, but we have little evidence of assemblage migrations. Most taxa which existed in the high-latitudes during the Early Tertiary were present in the mid-latitudes contemporaneously.

Taxa which flourished in the high latitudes 60 million years ago were those with tolerances sufficiently broad to accommodate the demands of the existing climatic regimes. During the Early Tertiary, warm ocean currents reached the north polar regions, moderating temperatures and helping create warm-temperate to sub-tropical climates. Regions of higher altitudes, or those more continental, may have experienced cooler temperate climates. However, the light regime (months of total darkness annually) would have been a limiting factor for many species. Our fossil collections indicate moderate species diversity in these high-latitude floras but an abundance of some taxa, such as *Metasequoia, Glyptostrobus, Cercidiphyllum* and ?birch.

Present climates of Canada are very different from those of the Early Tertiary. Gradual global cooling altered the moist warm-temperate cosmopolitan system of the Early Tertiary to the present regime of moist and dry-temperate, boreal, tundra, and ice cap climates. The effect of this change on the earlier floras of Canada was dramatic and often devastating. Many of the dominant tree species of these Early Tertiary forests, such as *Metasequoia, Glyptostrobus*, and *Cercidiphyllum* are relictual today, inhabiting isolated areas in Asia. Some taxa became extinct, while others experienced direct adaptation, diversification and perhaps southward migration.

As we have indicated, *Thuja* or *Thuja*-like members of the Cupressaceae were abundant and apparently widespread

throughout the Northern Hemisphere as elements of the Early Tertiary geoflora. Since that time there has been extensive reduction in the range of the genus. One of the major reasons for this reduction and the present disjunction of North American taxa is mid-continental drying during the latter half of the Tertiary. Further severe reduction and range restriction of North American and Asian species occurred during the Pleistocene glacial advances and, in Europe, glaciation effected the extinction of all *Thuja*. Extant North American species appear to be well-adjusted and increasing their range, while their Asian relatives may be declining.

North American *Thuja* species may have origins in the Ellesmere Island cedar. Both *T. plicata* and *T. occidentalis* bear cones very similar to the fossil and may be descendants from the same lineage. However, the history of present distributions of these species remains speculative in the absence of additional fossil evidence. The Early Tertiary range of the cedar from Ellesmere Island may have extended to regions presently occupied by extant *Thuja* as elements of the extensive geoflora. Subsequently, isolation leading to speciation and disjunction may have given rise to the present situation. Conversely, southward migration of ancestral stock from the high latitudes may have been followed or accompanied by evolution in isolation during the early Tertiary, with subsequent elimination of the more northern species.

The discovery of this fossil cedar from Ellesmere Island has allowed us to describe an Early Tertiary Canadian cedar, and is contributing significantly to our understanding of cedar evolution, particularly for *Thuja*. In addition, our plant megafossil collections from the High Arctic are providing valuable data for our study of origins and evolutions in Canadian temperate floras. We are now developing some appreciation for the diversity, distribution, and floristics of Early Tertiary high-latitude floras.

Acknowledgments

Thanks are due to Dr. D.G. Edwards, Pacific Forest Centre, Victoria, B.C. for providing fresh cedar branches; to the Northern Scientific Training Program of the Department of Indian Affairs and Northern Development for financial assistance to E.E. McIver during field work in the arctic; and to the National Research Council of Canada for financial assistance (a postgraduate scholarship to E.E. McIver and operating grants U0135 and A1334 to J.F. Basinger).

References

Baird, A.M. 1953. The life history of *Callitris*, Phytomorphology, 3:258-284.

Bell, W.A. 1949. Uppermost Cretaceous and Paleocene floras of western Alberta. Bull. Geol. Surv. Canada, 13:1-231.

_____ 1957. Flora of the Upper Cretaceous Nanaimo group of Vancouver Island, British Columbia. Mem. Geol. Surv. Canada, 293:1-84.

Berry, E.W. 1930. The past climate of the North Polar Region. Smithsonian Misc. Collections, 82:1-29.

_____ A preliminary contribution to the floras of the Whitemud and Ravenscrag Formations. Mem. Geol. Surv. Canada, 182:1-107.

Brown, R.W. 1962. Paleocene flora of the Rocky Mountains and Great Plains. Prof. Pap. U.S. Geol. Sur. 375:1-119.

Chaney, R.W. and Axelrod, D.I. 1959. Miocene floras of the Columbia Plateau. Carn. Inst. Wash. Publ. 617:1-237.

Dalimore, W. and Jackson, A.B. 1966. A handbook of Coniferae and Ginkgoaceae. 4th Ed. Revised by S.G. Harrison. Edward Arnold, London.

Dawson, J.W. 1889. On fossil plants collected by Mr. R.A. McConnell, on Mackenzie River, and by Mr. T.C. Weston, on Bow River. Trans. Roy. Soc. Canada, 7:69-74.

Eckenwalder, J.E. 1976. Re-evaluation of Cupressaceae and Taxodiaceae: a proposed merger. Madroño, 23:237-300.

Florin, R. 1963. The distribution of conifer and taxad genera in time and space. Acta Horti Berg. 20:121-312.

Graham, A. 1972. Outline of the origin and historical recognition of floristic affinities between Asia and eastern North America. in A. Graham (ed.), Floristics and Paleofloristics of Asia and Eastern North America. Elsevier, Amsterdam.

Heer, O. 1868. Flora fossilis arctica, 1, Zurich.

_____ 1870. Die miocene Flora und Fauna Spitzbergens. Kungl. Svenska Vetensk. Akad. Handl. 8:1-98.

_____ 1874. Nachtrage zur miocene Flora Grönlands. Kungl. Svenska Vetensk. Akad. Handl. 3:1-29.

_____ 1878. Miocene Flora der Insel. Sachalin. Flora fossilis arctica, 5, Zurich.

_____ 1882. Die fossile Flora Grönlands I. Flora fossilis arctica, 6, Zurich.

_____ 1883. Die fossile Flora Grönlands II. Flora fossilis arctica, 7, Zurich.

Hickey, L.J. 1984. Eternal summer at 80 degrees north. Discovery, 17:17-23.

Huzioka, K. and Vemura, K. 1973. The Late Miocene flora of Akita Prefecture, northeast Honshu, Japan. Bull. Nat. Sci. Mus. Tokyo, 16:661-738.

Li, H.L. 1952. Floristic relationships between Asia and eastern North America. Trans. Amer. Philos. Soc., New Ser. 42:371-429.

_____ 1953. A reclassification of *Libocedrus* and Cupressaceae. J. Arnold Arb. 34:17-34.

Manum, S. 1962. Studies in the Tertiary flora of Spitzbergen, with notes on Tertiary floras of Ellesmere Island, Greenland and Iceland. Norsk. Polarinst. Skr. 125:1-127.

Miall, A.D. 1986. The Eureka Sound Group (upper Cretaceous-Oligocene), Canadian arctic islands. Bull. Can. Pet. Geol. 34:240-270.

Newberry, J.S. 1868. Notes on the later extinct floras of North America, with descriptions of some new species of fossil plants from the Cretaceous and Tertiary strata. Ann. Lyceum Nat. Hist. New York, 9:1-76.

Ricketts, B.D. 1986. New formations in the Eureka Sound Group, Canadian arctic islands. in Current Research, Part B, Geological Survey of Canada, Paper 86-1B:363-374.

Ricketts, B.D. and Embry, A.F. 1984. Summary of geology and resource potential of coal deposits in the Canadian Arctic Archipelago. Bull. Can. Pet. Geol. 32:359-371.

Schweitzer, H-J. 1974. Die Tertiaren Koniferen Spitzbergens. Palaeontographica Abt. B. Palaeophytol. 149:1-89.

Sveshnikova, I.N. and Budantsev, L.Y. 1969. Florulae fossilis arcticae I. Nauka, filia Leningr. 1-120.

Wolfe, J.A. 1969. Neogene floristic vegetation history of the Pacific Northwest. Madroño, 20:83-110.

A FIELD SURVEY OF RESPIRATION RATES IN LEAVES OF ARCTIC PLANTS

Amy McNulty, W. Raymond Cummins and Andrew Pellizzari

Department of Botany, Erindale Campus, University of Toronto, Mississauga, Ontario L5L 1C6

Level: A. McNulty, Master's;
A. Pellizzari, Bachelor's

Abstract

In a survey of several plant species found at Churchill, Manitoba in the transition zone between the low and subarctic regions, we measured respiration in terms of total respiration and alternate pathway respiration rates. Arctic plants exhibit higher rates of total respiration than temperature species. As well, arctic species have higher rates of the alternate (cyanide insensitive) respiration. No energy is conserved as ATP in this alternate pathway which is thus considered to be wasteful. There is a negative correlation between height and alternate pathway activity. Shorter plants have higher rates of alternate pathway respiration. More alternate pathway activity may mean that there is less energy in the form of ATP available for growth. A shorter growth habit keeps these plants in the still air close to the ground. This prevents cooling, water loss and physical damage due to wind abrasion. Thus plants with high rates of alternate pathway respiration may be better adapted to the arctic environment. Respiration in arctic plants can be understood in terms of temperature, photoperiod and heat dissipation.

Key words: Subarctic, plant respiration, alternate pathway, cyanide insensitive.

Résumé

Ces chercheurs ont mesuré le volume total de la respiration et des respirations auxiliaires de plusieurs plantes identifiées à Churchill, Manitoba, dans la zone de transition entre l'Arctique méridional et la région subarctique. Les plantes de l'Arctique utilisent plus largement la respiration auxiliaire (insensible au cyanure). Aucune énergie n'est stockée sous forme d'acide adénosine triphosphorique par cette respiration auxiliaire, qu'on considère donc comme improductive. Il existe une corrélation négative entre taille de la plante et utilisation de la respiration auxiliaire. Les plantes de petite taille ont un taux de respiration auxiliaire plus élevé, ce qui peut signifier que l'énergie stockée sous forme d'A.A.T. et disponible pour la croissance est moins abondante. La faible croissance habituelle de ces plantes les maintient dans une couche d'air stationnaire près du sol. Elles sont ainsi protégées du refroidissement, de la déshydratation et des dégâts dus au vent. Ainsi les plantes dont le taux de respiration auxiliaire est élevé seraient-elles mieux adaptées au milieu arctique. On peut considérer la respiration des plantes arctiques sous les angles de la température, de la photopériodicité et de la perte de chaleur.

Mots-clés: Région subarctique, respiration végétale, respiration auxiliaire, insensible au cyanure.

Note

Paper accepted for publication in *Arctic*.

THE BEAUFORT SEA BOUNDARY DISPUTE (CANADA/ALASKA): A DISCUSSION

Peter Murphy

Department of Geography, Carleton University, Ottawa, Ontario K1S 5B6

Level: Bachelor's

Abstract

"A boundary dispute is not, it becomes" is a statement derived from the concept "boundaries are not, they become". The Beaufort Sea boundary dispute is an example of an international maritime boundary dispute between Canada and the United States. Both claims forwarded by Canada and the United States are based upon different interpretations of the emerging Law of the Seas (LOS) and international case law. The U.S. boundary claim is based upon an "equidistant" measurement from the Canada-U.S. Beaufort Sea coast. The Canadian boundary claim is based on the extention of the Alaska/Yukon land boundary. The two overlapping boundaries create a pie shaped zone, or ocean-space, of conflicting jurisdictions in the Beaufort Sea coastal region. As a result, a high degree of uncertainty exists. State sovereignty, economic potential, and prestige are some of the factors that impel the two coastal states of the Beaufort Sea region to press their respective boundary claims: "A boundary dispute is not, it becomes".

Key words: Beaufort Sea, boundary dispute, international law, Canada-U.S. relations.

Résumé

L'idée selon laquelle les frontières n'existent pas, mais qu'elles finissent par s'imposer, est à l'origine de cette observation: «Les litiges frontaliers se développent d'eux-mêmes». Le litige au sujet des limites maritimes internationales dans la mer de Beaufort est un exemple de contestations similaires entre le Canada et les É.-U. Les revendications formulées tant par le Canada que par les É.-U. sont fondées sur le principe de l'équidistance de la limite par rapport aux côtes canadienne et étatsunienne de la mer de Beaufort. Les revendications canadiennes sont basées sur l'extension de la frontière terrestre entre l'Alaska et le Yukon. Ces deux limites revendiquées forment un éventail à l'intérieur duquel les eaux marines donnent lieu à des conflits de souveraineté qui sont la cause de nombreuses incertitudes. La souveraineté des États intéressés, le potentiel économique de l'aire contestée et le prestige à maintenir sont les principaux motifs contraignant les deux États riverains à poursuivre leurs revendications sur cette zone de la mer de Beaufort: «Les litiges frontaliers se développent d'eux-mêmes».

Mots-clés: Mer de Beaufort, litige frontalier, Droit de la mer, rapports canado-américains.

Introduction

It has been said that a boundary is not, it becomes (Jones, 1959). Perhaps this leads to the corollary; a boundary dispute is not, it becomes. Moreover, political geography has shown that political boundaries, regardless of the manner in which they are demarcated, are constructs of the human mind and will ultimately vary over time and space (Hartshorne, 1937; East, 1936; Boggs, 1940; Jones, 1945 and 1959; and Prescott, 1978).

Ocean boundaries are no less the constructs of the human mind and so are the disputes that result from the conflicting claims put forward by adjacent and opposite coastal states. Whether one views the expansion of coastal state jurisdiction over the adjacent waters of the world as a "scramble" for ocean-space similar to that of the Eighteenth century colonial powers' "scramble" for the territory in the "new world" (Prescott, 1978: 132), or as a continuation of the "ocean enclosure movement" in the post WWII period (Alexander, 1983: 561–595), or as a positive development in terms of resource development and pollution control by the coastal states themselves (Knauss, 1985: 209–216), boundary disputes between adjacent and opposite coastal states are common on the world stage. By the late seventies there were approximatey two-hundred and fifty-two maritime boundary disputes that had yet to be settled by the states involved (Hodgson and Smith, 1979: 426). Smith states that there are nearly four hundred maritime boundary disputes that are currently unresolved (Smith, 1985: 3). This paper will focus on the Beaufort Sea boundary dispute between Canada and the United States.

The dispute over the Beaufort Sea boundary is essentially a positional dispute involving the United States and Canada. Each state has a claim to a different boundary and the result is a pie shaped wedge of disputed ocean-space approximately 6180 square nautical miles (Beauchamps, 1983:8). Canada

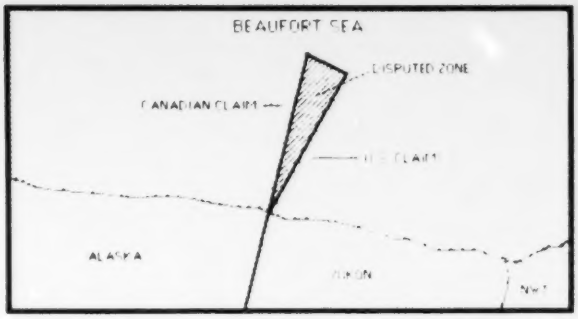


Figure 1. The Beaufort Sea boundary dispute, "Canada's claim" is the 141st parallel.

claims a boundary that follows the 141st parallel. The United States claims a boundary based on the equidistant measurement from the shoreline beginning at the point where the Yukon and Alaskan boundaries meet the coastline (Fig. 1).

The Beaufort Sea dispute has gained in importance since 1969. At that time oil was discovered in Prudhoe Bay, Alaska. In 1982, the Prudhoe oil field was producing 1.5 million barrels of crude oil per day (Thomas and Thomas, 1982:350). Geological surveys of the disputed zone indicate that possible hydrocarbon resources may exist (Frederick, 1979:33). Therefore the boundary that is ultimately agreed on may yield the state with jurisdiction over the area with the opportunity to exploit the extensive hydrocarbon resources. A single boundary or some other kind of formal arrangement must be agreed to first. Drawing on Gottman's "security-opportunity" concept, which is primarily attributed to "land" territory, it is not difficult to expand this concept onto disputed "ocean-space"; as long as sovereignty and functional control remain unsecured in a disputed area, opportunity in the form of hydrocarbon development and an appropriate legal/institutional regime required to control it remain unlikely.

The factors, both past and present, that have contributed to this dispute are complex. These factors are: a treaty signed by two Great Powers of the nineteenth century in 1825; the popularization of the sector theory; the discovery of hydrocarbon deposits, described above, in the vicinity of the disputed zone and the subsequent leasing activity within the disputed zone; the development of the modern regime of the law of the seas (LOS) and coastal state maritime zone claims; and the differing boundary claims forwarded by Canada and the U.S. in the Beaufort Sea. The internal organization of this paper will follow the sequence of the factors listed above.

The Treaty of 1825

In 1825 Great Britain and Imperial Russia concluded a treaty that delimited the boundary between their respective land holdings in north western North America—today known as Alaska and the Yukon. In 1867 Russia sold its land holdings in the area to the United States under the Cession of Alaska Treaty. Meanwhile the Dominion of Canada was created out of an amalgamation of Great Britain's eastern colonies of British North America. The following year the *Rupert's Lands Act* was passed in the Canadian Parliament and Rupert's Land and the North-West Territories were ceded

to Canada (Nicholson, 1979:57). Thus, within a two year period the ownership of the adjacent territories and the legal title of the treaty that delimited the common *land* boundary that separated them changed twice; Imperial Russia to the U.S. and Great Britain to the Dominion of Canada.

At that time the most pressing jurisdictional issue centered upon the ownership of the Arctic Islands. Mining exploration activity by two American expeditions caused the Canadian government to issue an Order in Council in 1880 and to pass the *Imperial Colonial Boundaries Act* in 1895 in order to formalize the transfer of the ownership of the Arctic Islands from Great Britain to Canada; the location of the Alaska-Yukon land boundary was still undetermined. Subsequently, a joint British-U.S. demarcation commission was formed in 1906 in order to delimit the 141st meridian land boundary. The joint commission stopped at the Beaufort Sea shoreline without delimiting a seaward extension. This fact is not surprising. At that time the concepts of extended jurisdiction over the continental shelf, extended economic zone, fishing zones, and pollution zones had not been devloped or codified in international law. The territorial sea was the only maritime zone that had been generally accepted by coastal states. The breadth of the territorial sea under this rule was measured by the maximum length of a "cannon shot", hence the "cannon shot" rule.

The earliest Canadian claim to the seaward extension of the 141st meridian was primarily based on the wording, which is in French, of Article III of the Treaty (Wang, 1981:21). This claim stressed that a *poleward* extension of the land boundary is defensible based upon the wording of the Treaty; "...Meridian line of the 141st degree, in its prolongation as far as the Frozen Ocean..." (Penlington, 1972:11). American counter-claims refuted the Canadian claim based on an interpretation of the wording of the 1825 treaty in which the phrase "as far as the Frozen Ocean" implies that the established "land" boundary was not intended to extend onto the Beaufort sea to the North Pole (Lawson, 1981: 230–232). A recent Canadian scholarly opinion seems to concur with the U.S. refutation based on the notion that the parties to the 1825 Treaty "could not have envisaged establishing a boundary for the continental shelf." (Pharand, 1984a: 754).

The sector principle

The first public official to propose the sector principal was Senator Pascal Poirier in the Canadian Senate in 1907. He proposed that a Canadian sector be established over the adjacent Arctic waters poleward. He went on to state that the "sector" would secure the mineral wealth of the Arctic Islands and allow Canada "to have the North Pole as a way out of the Dominion" (Nicholson, 1979: 69). However, a map delimiting the Arctic sector was published by the Department of the Interior, predating Senator Poirier's proposal by three years. Since that time almost all of the maps published in Canada, governmental and otherwise, delimit Canada's offshore Arctic boundary according to the sector principle (Pharand, 1973: 134–135).

Canada has never formally proclaimed the sector principle in its entirety either unilaterally or under any international convention. In 1956, the minister for Northern Affairs, Jean Lesage stated "our claim since 1903 has been to all the land within these lines. But we have never adhered to a broad sector theory. If you adhere to the general sector theory you claim that you have sovereignty over waters beyond your territorial waters. We have never done that" (Lawson, 1981:232). Although this statement and others made by politicians and experts on the status of Arctic waters has indicated a reluctance to accept the sector principle it remains true to this day that the image most Canadians have of the northern offshore boundaries of their country is equated with the principle.

Hydrocarbon development

In 1968 Atlantic Richfield Corporation and Exxon Corporation (formerly Humble Oil) discovered oil under Prudhoe Bay. The discovery has had far reaching effects for both countries. If the discovery is taken within the context of the two major oil price increases of the last fifteen years, then the subsequent emergence of incentive-type policies adopted by Canada and the U.S. in the area of frontier hydrocarbon exploration is not surprising. Driven by the goals of energy self-sufficiency and security, both states have adopted various energy policies since 1968.

In 1982 it was estimated that the yearly output of crude oil from the field amounted to 20 percent of the U.S. total (Bloomfield, 1982: 95–96). Estimates for the Canadian Beaufort Sea region range from 6.9 to 34 billion barrels of crude oil and up to 60 trillion cubic feet of gas (Hoos, 1983: 305).

Both countries have issued hydrocarbon exploration leasing rights in the disputed zone. Canada initiated this practise in 1971 while the U.S. issued permits for tracts inside the disputed zone in the late 1970's but withdrew them after Canada protested the sale. The U.S. has recently issued new leases in the disputed zone which total more than 7.7 million square acres (Parkes, 1986). This situation has heightened the uncertainty over the status of this pie shaped ocean-space. Competing exploration companies risk losing potentially large sums of capital if their lease tracts are found to be within the other state's jurisdiction.

Transportation issues relating to the status of the disputed zone are potentially significant. The voyages of the Manhattan and the Polar Sea could be viewed as precursors to the projected traffic through the Northwest Passage and the disputed zone. With an increase in shipping, the question of which jurisdiction should apply in the disputed zone and in which system negligent shippers and drill rig operators will be prosecuted is a complicated issue.

The Law of the Seas

The modern Law of the Seas (LOS) represents a large body of international law. The evolution of the LOS is the result of an amalgamation of accepted state practices and customary and treaty law; judicial decisions of the International Court of Justice (ICJ) are also considered a partial source of international law since the court interprets existing laws and conventions for each case that appears before it.

Once the ICJ receives a maritime boundary dispute it must consider two things aside from the positions argued by the coastal states: LOS as defined by UNCLOS III and precedent.

Since the establishment of the International Law Commission (ILC) in 1947, three United Nations Conventions on the Law of the Seas (UNCLOS I, II, and III) have been convened. Although the latest UNCLOS treaty has not been ratified by the required number of states in order to consider it to be entered into force, it remains that many of the states that have not signed and/or ratified the treaty have enacted legislation that mirrors specific concepts in the UNCLOS III document. Without casting the U.S. as the modern day Grotius, the U.S. has consistently sought to maintain the 'freedom of the seas' notion that owes its philosophical roots to the true Hugo Grotius and his concept of the Mare Liberum. Conversely, it would be inappropriate to cast Canada as the modern day Selden although Canadian ocean policy has consistently sought to control 'its Arctic waters based partly on the environmental impact of industrialization in the Arctic and on sovereignty questions rather than rely on the pure application of the Mare Clausem which was primarily concerned with strategic and mercantile controls' (see Alexander, 1981).

The latest UNCLOS treaty contains several articles that deal with the delimitation of maritime boundaries and jurisdictions. Twenty four articles of the Law of the Seas Convention (1982) pertain to maritime boundary delimitation (Arts. 3 to 16, 33, 47, 48, 50, 57, 74, 75, 76, 83, 84, and 121) (see Theutenberg, 1984). All maritime jurisdictions are measured from "baselines" that are either delimited by the mean low water mark of the shoreline or by a system of straight baselines; the latter is important to the current Canadian claim that the waters of the Arctic Archipelago are "internal". Articles 15, 74, and 83 outline the manner in which the territorial sea, the exclusive economic zone (EEZ), and the continental shelf boundaries between adjacent (and opposite) jurisdictions should be delimited. Article 15 calls for the "median" approach for the delimitation of territorial sea boundaries. Articles 74 and 83 state that an "equitable" approach based on special circumstances *could* be undertaken for EEZ and continental shelf boundary delimitation.

It remains that two or more coastal states can resolve a boundary dispute by negotiation. Once negotiations have failed the parties may bring the dispute before the ICJ. Recent maritime boundary dispute judgements by the ICJ indicate that there are at least three important factors relating to maritime boundary dispute adjudication. In the *North Sea Continental Shelf Case* (1969), the Court ruled that the delimitation of a maritime boundary does not have to adhere to the equidistant principle (the basic U.S. position on the position of the Beaufort Sea boundary). In the *Tunisia-Libya Continental Shelf Case* (1982) the Court delimited the boundary in question under the equitable principle and rejected the notion that equidistant delimitation was mandatory (Smith, 1985). In the *Gulf of Maine Case* the ICJ decision, among other things, implicitly rejected the natural prolongation argument and adopted a modified equidistant approach in order to delimit the three main segments of the final boundary (Cooper, 1986). Moreover, in the *Gulf Case* Canada adopted a form of equidistance and the U.S. adopted a special circumstances approach. Interestingly, both states have adopted opposite positions in the Beaufort Sea boundary dispute.

Under the LOS Canada and the U.S. have adopted several maritime jurisdictional zones. In internal waters, all waters landward of established baselines (or shorelines), coastal states have undivided sovereignty. In the territorial sea (12nm for Canada and 3nm for the U.S.) coastal states can exercise sovereignty except that all ships have the right of innocent passage. Beyond the territorial sea maritime zones claimed by coastal states are "functional" since limited control is accorded to the claimant states. Both states have enacted several pieces of legislation governing activities in their respective maritime zones.

There are five functional zones claimed by Canada that apply to the Arctic/Beaufort Sea. In January, 1986 the Federal Cabinet promulgated an Order-In-Council that delimits the baselines around the Arctic Archipelago and thereby created a new zone of internal waters for Canada. In "drawing" these baselines the Federal government enables the various Acts enacted by the Canadian Parliament to be more accurately measured. The *Arctic Waters Pollution Prevention Act* (AWPPA) extends Canada's pollution control to a 100 mile zone in and around the waters of the Arctic Archipelago. The *Act* classifies ships according to their construction design. Shipping control zones were created in order to control ship movement throughout the AWPPA area. International acceptance of the Act was bolstered by the inclusion of Article 234 in the Third Law of the Seas Conference (UNCLOS) (McCrea and Goundrey, 1982: 197–223). Article 234 allows Arctic states to take protective measures against pollution within a 200 mile limit (Theutenberg, 1984: 14–15). The *Canadian Territorial Seas and Fishing Zone Act* gives Canada control over fishing conservation within a 200 mile zone; this Act was amended in 1970 in order to extend the territorial sea limit from 3 to 12 miles. The *Canada Petroleum Resources Act* permits the Minister of Indian Affairs and Northern Development to issue drilling permits out to 200 miles or the edge of the continental shelf, or whichever is furthest. The *Canada Shipping Act* prohibits ships from polluting between 100 and 200 miles offshore.

There are two important maritime jurisdictional zones claimed by the U.S. in the Arctic beyond the 3 mile territorial sea. Under the 1945 Truman Declaration the U.S. asserted control over the adjacent continental shelf. This particular declaration is significant since it is the first claim made by a coastal state that went beyond the limit of the territorial sea, a significant contrast to the commonly held belief that the U.S. has been one of the leaders of the group of developed coastal states that traditionally opposes any form of 'creeping jurisdiction'. In 1958 the U.S. altered the Truman Declaration slightly by signing the first Law of the Sea Convention. The second important boundary development adopted by the U.S. was the 200 mile extended economic zone (EEZ) by the Reagan administration (Dept. of State 1983: telegram 3/11/83). The U.S. 200 mile EEZ closely resembles Article 57 of the UNCLOS III (Westermeyer, 1984: 242–267).

As a result of the boundary dispute two sets of claimed territorial seas and functional zones overlap inside the disputed area. Because of this overlap the purposes of these zones are lost since both states claim exclusive jurisdiction. If a disaster occurs the question as to which government will be responsible will undoubtedly increase the tension over the dispute. A similar situation could arise over the control of shipping in the disputed zone.

The claims restated

The current U.S. position is based on the interpretation of the 1958 Continental Shelf Convention, which Canada and the U.S. signed and are therefore mutually bound, and customary international law. Moreover, the lack of clarity in international law pertaining to boundary delimitation means that customary international law must be applied in unison with the 1958 Treaty.

The decision rendered in the North Sea Cases was that the natural prolongation of the shelf was divided according to three broad categories based on the physical landscape of the coastline and area in general. The U.S. refutes Canada's 'special circumstances' approach and instead proposes that 'equidistance' is an appropriate principle for determining a maritime boundary when there are no special circumstances in the area and when equidistance results in a boundary in accordance with 'equitable principles'. (Bloomfield, 1981:99). According to the U.S. State Department no special circumstances exist in the Beaufort Sea (U.S. State Department memo in Lawson, 1981: 241–242).

The Canadian claim relies on the 1958 Continental Shelf Convention but with an emphasis on the expression 'special circumstances'. Although the 1958 Convention failed to define what 'special circumstances' meant, Canadian legal opinion maintains that both the North Sea cases and the Continental Shelf Case between France and the U.K. have important bearings on the meaning of 'special circumstances' (Pharand, 1984b: 746–747). It is argued that the former case did not establish any firm rules regarding boundary delimitation while the latter case was decided on a "combined equidistant-special circumstances approach" (International Court Of Justice in Pharand, 1984b: 747).

Although it seems that the reliance on a historical claim based on the 1825 Treaty appears to have a relatively weak legal footing, recent legal opinion suggests that the Canadian position stressing the continued use by Canada of the 141st longitude as the western boundary in Canadian maritime legislation since 1965 is justified because, as one scholar states "the continuation in the seaward delimitation of the land frontier constitutes an accepted method of continental shelf delimitation" (Pharand, 1984b: 754). Thus the Canadian claim to a 200 mile extension of the 141st longitude need not only rely on the interpretation of a treaty agreed on by the Great Powers of the 19th century. Instead the Canadian claim can draw on current international law.

If both states take the dispute to the International Court of Justice (ICJ) and formally base part or all of their boundary claims on one line (i.e. the same line would demarcate the 200 mile EEZ, fishing zones), it is interesting to note that in the Gulf of Maine decision Article 6 of the 1958 Continental Shelf Treaty was held to be insufficient to delimit anything other than a continental shelf boundary. According to Legault the Gulf of Maine decision "brings us back to the cardinal role of geography in maritime delimitation" where no 'special circumstances' exist (Legault, 1985: 475). Therefore the nature and shape of the coast along the Beaufort Sea could play a more important role than previously thought. If it is established that special circumstances do exist, then the basis for the Canadian claim will be strengthened.

Conclusion

There is no mistaking the importance of the Beaufort Sea boundary dispute in Canada-U.S. relations. Political and economic implications continue to create a situation in which bilateral agreement is difficult and third party arbitration is undesirable. Perhaps a solution to this conflict would have been found by now if there were no riches at stake, no security questions involved, and no possibility of the loss of prestige: a boundary dispute is not, it becomes.

References

Alexander, Lewis M., "The Ocean Enclosure Movement: Inventory and Prospect", in San Diego Law Review, Vol. 20, no. 3, 1983.

Armstrong, Terence, Rogers, George, and Graham Rowley, The Circumpolar North, London: Methuen and Company Ltd., 1978.

Barnes, P. W., Schell, D. D. and E. Reimnitz, The Alaskan Beaufort Ecosystems and Environments, Orlando: Academic Press Inc. 1984.

Beauchamps, Kenneth, "International Legal Issues in Arctic Waters", in Northern Perspectives, vol. 11, no. 5, December 1985, pp. 7–12.

Bloomfield, Lincoln P., "The Arctic: The Last Unmanaged Frontier", in Foreign Affairs, vol. 60, no. 1, Fall 1981, pp. 87–105.

Boggs, S. W., "Problems of Water Boundary Definition: Median Lines and International Boundaries Through Territorial Waters" in Geographical Review, vol. 27, pp. 445–56.

Burnet, Peter, "Paper Sovereignty", in Northern Perspectives, vol. 13, no. 3, May-August 1985, pp. 1–8.

Canada, Department of External Affairs, Some Examples of Current Issues of International Law of Particular Importance to Canada, Photocopy, Oct. 1985: 35pp.

_____, Department of Transport, Department of Transport Brief to the Special Committee of the Senate on the Northern Pipeline, Sept. 1982.

_____, Ministry of Transportation, Control of pollution from shipping in waters under Canadian Jurisdiction, Ottawa: DOT/Coast Guard, 1981.

Carroll, John, "Water Resources Management as an Issue in Environmental Diplomacy", Natural Resources Journal, 1986, vol. 26(2): pp. 207–220.

_____, Environmental Diplomacy, Ann Arbor: Univ. of Michigan Press, 1983.

Charney, Jonathan, "Ocean Boundaries Between Nations: A Theory for Progress", American Journal Of International Law, 1984, vol. 78(3): pp. 582–606.

Conant, Melvin, "The Call of the Arctic", in Oceanus, vol. 25, no. 4, Winter 1982/83, pp. 51–57.

_____, "The Great Arctic Energy Rush", in Business Week, January 24th, 1983, pp. 52–56.

Dacks, Gurston, A Choice of Futures: Politics in the Canadian North, Methuen: Toronto, 1981.

Franson, Robert, "The Future Development of Canada's North: A Legal and Political Perspective", Alternatives, 1981, vol. 10(1): pp. 43–50.

Gottman, Jean, The Significance of Territory, University of West Virginia Press, 1978, 178pp.

Griffith, Franklin, A Northern Foreign Policy, Toronto: Canadian Institute for International Affairs, Wellesley Papers no. 7, 1979.

Hartshorne, Richard, "Suggestions on the Terminology of Political Boundaries" in Annals of the Association of American Geographers, vol. 26, pp. 56–7.

Hodgson, Robert and R. Smith, "Boundary Issues Created By the Extended National Jurisdiction." The Geographical Journal, 1979, 4: pp. 423–433.

Johnston, Douglas M., Arctic Issues in the 1980's, Proceedings: Law Institute of Hawaii, University of Hawaii and Dalhousie Ocean Studies Programme, Halifax: Dalhousie Ocean Studies Programme, 1982.

Jones, Stephen B., Boundary Making: A Handbook for Statesmen, Washington: Office of the Printer, 1945.

_____, "Boundary Concepts in the Setting of Place and Time" Annals, Association of American Geographers, 1959, vol. 49(3): 241–255.

Knauss, John, "Creeping Jurisdiction and Customary International Law." Ocean Development and International Law, 1985, vol. 15: pp. 209–216.

Lawson, Karin. "Delimiting Continental Shelf Boundaries in the Arctic: The U.S.-Canada Beaufort Sea Dispute" Virginia Journal of International Law. 1981. pp. 221-248.

Logan, R. M. Canada, the United States and the Third Law of the Sea. Montreal: C. D. Howe Institute. 1974.

Marshall, James K., "Disputed Areas Influence OCS Leasing Policy", in Offshore, May 1985, pp. 99-102.

McCrea, D. M., "Arctic Waters and Canadian Sovereignty", in International Journal (Canada), Toronto: Canadian Institute Of International Affairs, no. 3, 1983, pp. 476-492.

_____, and D. J. Goundrey. Environmental Jurisdiction in Arctic Waters Extent of Article 234". U.B.C. Law Review. 1982. vol. 16: pp. 210-215.

Mills, Hal. "Ocean Policy Making in the Canadian Arctic" in Ocean Policy in the Arctic. Ottawa: Canadian Arctic Resources Committee. 1984: pp. 11-47.

Nelson, J. G., The Scottish and Alaskan Offshore Oil and Gas Experience and the Canadian Beaufort Sea, Ottawa: Canadian Arctic Resources Committee, 1981.

Nicholson, Norman L. The Boundaries of the Canadian Confederation. Toronto: Macmillan Ltd. 1979.

Oxman, Bernard. "Summary of the Law of the Sea Conference" Journal of the American Law Association. 1983. 69: 156-170.

Parkes. J. G. M., Personal Communication, June 1986.

Penlington, Norman. The Alaskan Boundary Dispute. Toronto: McGraw Hill Ryerson Ltd. 1972.

Penney, Ronald G., "The Atlantic Accord: A Model of Cooperative Federalism" Resources. 1986. 14.: pp. 1-3.

Pharand, Donat (a). "The Legal Regime of the Arctic", International Journal. 1984. vol. 31: pp. 742-799.

_____ (b). International Straits of the World: The Northwest Passage and the Arctic Straits. Dordrecht: Martinus Nijhoff Publishers, 1984.

Prescott, John R. V., Boundaries and Frontiers, London: Croom Helm Press, 1978.

_____, The Political Geography of the Oceans, New York: John Wiley and Sons Ltd., 1971.

Shusterich, Kurt, "International Jurisdictional Issues in the Arctic". Westermeyer, W. and S. Shusterich (eds.). United States Arctic Interests: The 1980's and the 1990's. New York: Springer-Verlag Press. 1985: pp. 240-267.

Smith, G. W. Canada and the Arctic Archipelago: 100 Years of Canadian Jurisdiction. Ottawa: DIAND. 1980.

Smith, R., National Claims to Maritime Jurisdictions, (5th Edition), Washington: Office of the Geographer, 1985.

Theutenberg, Bo J. The Evolution of the Laws of the Sea: A Study of Resources and Strategy with Special Regard to the Polar Areas. Dublin: Tycooly International Publications Ltd. 1984.

Thomas, W. C. and M. E. Thomas, "Public Policy and Petroleum Development: The Alaska Case", in Arctic, 1980, Vol. 35, no. 3, pp. 349-357.

United States, Department of State, "Maritime Boundaries Between the U.S. and Canada. Photocopy. Public Notice 506. Nov. 1, 1976.

Vanderzwaag, David, and D. Pharand. "Inuit and the Ice: Implications for Canadian Arctic Waters," The Canadian Yearbook of International Law. 1983. vol. 21: pp. 53-84.

Vaucher, Mark. "Prospective Maritime Jurisdictions in the Polar Seas." map insert. Annals, Association Of American Geographers. 1983. vol. 73(4).

Wang, Erik. Canada-U.S. Fisheries and Maritime Boundary Negotiations: Diplomacy in Deep Water. Behind the Headlines. Toronto: Canadian Institute of International Affairs. no date.

Westermeyer, William E. and Kurt M. Shusterich (eds.), United States Arctic Interests: The 1980's and the 1990's, New York: Springer-Verlag Ltd., 1984.

_____, "United States Arctic Interests: Background For Policy" Westermeyer and Shusterich (eds.). United States Arctic Interests: The 1980's and the 1990's. New York: Springer-Verlag, 1984: pp. 1-9.

Whebell, C. F. J. "Drawing the Line in the Arctic". The Globe and Mail. Toronto; daily newspaper. 1969. Oct. 1: p.1.

Young, Oran. "The Age of the Arctic". Foreign Policy. winter 1985-86: pp. 160-170.

THE DEVELOPMENT OF NORTHERN NURSING IN DESMARAIS, ALBERTA

Wendy Neander

University of Alberta, Edmonton, Alberta T6G 2E5

Level: Master's

Abstract

This paper is a brief overview of the development of northern nursing in Desmarais, Alberta and the surrounding settlements of Wabasca and Sandy Lake. The focus of the paper is on the Sisters of Providence, who were the foundresses of nursing in Desmarais. The intention of this paper is to promote a general understanding of the vital role played by the Sisters from the initial establishment of lay nursing to the more sophisticated practice of present-day registered nursing. The basis for the research for this paper was primarily the "Chronicles of the Sisters of Providence." Information was also obtained from interviews with retired sisters and other knowledgeable individuals still residing in Desmarais.

As in the pre-Nightingale years the Sisters had no formal nursing education until 1929 when the first graduate nurse arrived in Desmarais. The Sisters' dedication to service was fundamental in establishing and maintaining nursing care of suitable quality in Desmarais. The Sisters' early recognition of their inability to provide an optimal level of care to the residents of the community led them to seek further skills and knowledge. This resulted in their introduction of professional nursing to the community. It was also evident that the Sisters sought outside specialized services for the community in accordance with its changing needs.

Key words: Northern Nursing, Desmarais, Alberta.

Résumé

L'auteure présente une vue synoptique du développement des soins infirmiers à Desmarais, Alberta, et dans les localités avoisinantes de Wabasca et de Sandy Lake. L'accent est mis sur les Soeurs de la Providence, qui furent les fondatrices des services infirmiers à Desmarais. L'auteure veut promouvoir une plus large compréhension du rôle vital assumé par les Soeurs, depuis l'établissement des soins infirmiers non professionnels jusqu'aux méthodes plus complexes des soins infirmiers professionnels utilisées actuellement. Ce sont les «Chroniques des

Soeurs de la Providence» qui ont servi de principale source de renseignements. D'autres informations ont été recueillies grâce à des entrevues avec les Soeurs à la retraite et d'autres personnes bien informées qui vivent encore à Desmarais.

Tout comme avant l'époque de Florence Nightingale, les Soeurs n'avaient reçu, avant 1929, aucune formation dans un établissement spécialisé. C'est alors qu'arriva la première infirmière diplômée. Le dévouement des Soeurs envers leurs malades était capital pour l'établissement et le maintien d'un service infirmier de qualité convenable à Desmarais. Les Soeurs ayant pris conscience qu'il leur serait impossible de fournir des soins de niveau optimal aux habitants de Desmarais, elles décidèrent d'acquérir des connaissances et des compétences techniques nouvelles. C'est ainsi qu'elles introduisirent les soins infirmiers professionnels dans la collectivité. Il est aussi évident que c'est en fonction de l'expansion des besoins nouveaux que les Soeurs se sont efforcées d'obtenir, pour la collectivité, des services spécialisés de l'extérieur.

Mots-clés: Soins infirmiers dans le Nord, Desmarais, Alberta.

Introduction

This paper is a brief overview of the development of northern nursing in Desmarais, Alberta and the surrounding settlements of Wabasca and Sandy Lake. The focus will be confined largely to the Sisters of Providence (who will also be referred to as "the Sisters" in this paper). The Sisters were the foundresses of nursing in Desmarais and it is the author's intention to present the reader/listener with a general understanding of the role played by them from the initial establishment of lay nursing to the more sophisticated practice of present-day registered nursing in a Woodlands Cree community.

Research for this paper was acquired primarily from the "Chronicles of the Sisters of Providence," journals which the Sisters have kept from their arrival in 1901 to the present day. Information was also obtained from interviews with retired Sisters and others still nursing in Desmarais. In addition, Woodland Cree residents of Desmarais were interviewed. The author, moreover, was employed from 1982 to 1984 at the St. Martin Health Centre in Desmarais as a registered nurse.

Initial outside contact with the Woodlands Cree

Desmarais remains today a semi-isolated Woodlands Cree community in north central Alberta. Obviously, the community's isolation was more pronounced at the turn of the 20th century when the Sisters of Providence first arrived. At that time, the inhabitants pursued a nomadic lifestyle in small family groupings, a lifestyle which can be observed currently in reduced form (Auger, 1986; Quesnelle, 1976). The small groupings and nomadic lifestyle were necessitated by the environmental constraints with respect to fishing, trapping, hunting and gathering.

To the author's knowledge, the Oblate Missionaries were the earliest recorded outsiders to reach Desmarais (Quesnelle, 1976). The Oblate's first contact with the Woodlands Cree of the area was in 1895 (Quesnelle, 1976). In 1896 the first priest, Father Dupé was sent to Desmarais to evangelize the Woodlands Cree. A second priest, Father Giroux, arrived in 1897. The two priests constructed St. Martin Mission on Lake Wabasca. The community that evolved around the mission was later named Desmarais. Fathers Dupé and Giroux visited the Woodlands Cree 134 kilometers to the south and 480 kilometers to the north. The purpose of the visits was to attend to what the priests believed were the spiritual needs of the Woodlands Cree. The establishment of the Mission created a permanent gathering place for the Woodlands Cree. Priests found themselves receiving more frequent contact with the Woodlands Cree and recognized the need for assistance at their Mission. In 1899, the Oblates summoned the Sisters of Providence for assistance with their work (Quesnelle, 1976).

Development of lay nursing — a generalist role

On June 13, 1901, Sisters Tiburce, Joseph Marie, Martin de Tour and Arnold embarked on a one month journey from Montreal to Desmarais (Quesnelle, 1976). The final stretch of the Sisters' journey (this part of the trip took 22 days) was accomplished by wagon, canoe and walking waist deep through swampy terrain (Quesnelle, 1976). The Oblates had specifically requested the Sisters to teach the Woodlands Cree children boarding at the St. Martin Mission. The Sisters envisioned their duties as an extension of the work of the Oblates. The Sisters' main purpose was to attend to what they believed were the spiritual needs of the Woodlands Cree ("Chronicles of the Sisters of Providence" (CSP), 1901). Following their arrival in Desmarais, the Sisters of Providence were to take on an expanded and differentiated role as a result of the Woodlands Cree's perception of them.

The Woodlands Cree recognized no distinction between an individual's spiritual and physical needs. As the Cree became more accustomed to the Sisters' presence, they came to them with afflictions. This practice by the Woodlands Cree initiated the development of lay nursing in Desmarais. The Sisters were required to play a generalist nursing role as various ailments arrived at their doorstep. The following accounts from the "Chronicles of the Sisters of Providence" illustrate that the lay nursing role developed to meet the needs of the Woodlands Cree.

Cholera was a contributing factor to the development of lay nursing in Desmarais. The Sisters of Providence serviced the infirm in January 1902 when 20 children of the mission school and two Sisters contracted cholera (CSP, 1902). The Sisters nursed all the infirm except an eight year old girl back to health. When the Sisters had no hope for the child's recovery, her family was summoned to be with her in her last hours. The girl's family bathed her completely and dressed her in her best clothes. To prevent the girl from tossing about restlessly as her death approached, she was laid between her father's legs. Other family members straightened her legs, joined her hands and closed her eyes. In the company of her family, the eight year old girl died. The Sisters were deeply affected by the girl's death, but admired her family's strength in allowing her to die peacefully with dignity (CSP, 1902). This anecdote is an example of early hospice care provided by the Sisters of Providence in collaboration with the family.

In addition to caring for children, the Sisters of Providence also cared for the elderly. In October 1902, the Sisters were

approached to care for four disabled elderly women. The Sisters of Providence housed and cared for these women until their deaths. One woman, Marie Ohimawwa Tharnow lived to be 106 years old (CSP, 1902).

Another interesting illustration of the Sisters' lay nursing role is this anecdote: In 1904, an Indian man walked all night to solicit the aid of the Sisters of Providence for his dying son. The priest and one of the Sisters paddled all day by canoe to reach the boy. When the Sister and the priest arrived at the boy's home they found him anorexic, febrile and suffering from a severely infected wound on his leg. After two days of nursing, the boy responded to the Sister's care. The boy's mother said to the Sister upon her departure, "My son will grow, will have white hair and never forget the Queen who came to nurse him (Quesnell, 1976: p.6).

In fulfilling their lay nursing role, the Sisters provided care to meet individual and group needs of the Woodlands Cree. As health care needs arose, the lay nursing services developed. The following sections provide more information on the development of lay nursing services in Desmarais.

The development of psychiatric nursing

Psychiatric nursing was another lay nursing service provided by the Sisters of Providence. In March 1903, a Woodlands Cree man troubled by a physical and mental condition referred to as "witigo" (in Cree) arrived at the mission (CSP, 1903). "Witigo" was described as a feeling of ice in the stomach and an uncontrollable cannibalistic urge (CSP, 1903). This man stayed with the Sisters for three weeks, while they fed him, administered medicine and spoke of God. After three weeks, the man left feeling cured, indicating that he would return if the ice in his stomach recurred. Following the departure of this man, three "witigo" victims, a husband, wife and daughter-in-law arrived at the mission. The husband and wife left the mission feeling free of the "witigo" after receiving the Sisters' care. After refusing food and medicine, the daughter-in-law left the mission still plagued by the "witigo" (CSP, 1903). A later incident (April 1907) involved a 40 year old man who travelled 480 kilometers after hearing of the Sisters success in curing the "witigo." To show his gratitude for the Sisters' nursing services, the 40 year old man asked the Sister Superior to be the Godmother of his child (CSP, 1907).

The "witigo" incidents required the Sisters to care not only for the physical afflictions of the Woodlands Cree but also care for the psychological/spiritual needs. Therefore, the Sisters' northern lay nursing role continued to expand as the Woodland Cree solicited their services.

It is interesting to note that "witigo" is still part of the present day Woodlands Cree vocabulary. Woodlands Cree interviewees have defined "witigo" as someone who overeats and is considered to be a pig. "Witigo" is used to insult people. The author has observed children teasing one another by calling them a "witigo." The oldest Woodland Cree interviewee (born 1915) had never witnessed a "witigo" as described in the Chronicles of the Sisters of Providence, but agreed with the description. It appears to the author that the "witigo" condition has disappeared among the Woodlands Cree in Desmarais.

The introduction of disease to Desmarais by outsiders

Another influential factor in the development of lay nursing in Desmarais was the introduction of communicable disease by outsiders coming to the community. The establishment of the Revillon Brothers' fur trading company in 1903 provided an avenue for the transmission of disease as outsiders entered the community for trade purposes. This form of disease transmission took its toll in December 1903, when the convent was converted to a hospital. The community was afflicted with cholera, chickenpox, pertussis and influenza. The Sisters were able to nurse all their patients back to health except for a two-and-a-half year old boy (CSP, 1903).

The increasing influx of outsiders to Desmarais brought more communicable disease to the community. The permanent structure of the mission and trading posts encouraged the development of closer settlements. The closer proximity to neighbors created easier access for disease transmission. This influx and proximity in turn increased the nursing responsibilities of the Sisters. As new and more severe disease was introduced to the community, the residents relied more and more on the Sisters for care. An example of the effect of the introduction of disease to the community occurred in the spring of 1920. The mail carrier arrived from Edmonton with the "Spanish Flu." The Woodlands Cree had no resistance to the illness and everyone contracted the flu. The Oblates assisted the Sisters in caring for the infirmed and buried the dead. All 56 pupils at the mission school contracted the disease. The Sisters nursed the students day and night, losing one boy to the illness (CSP, 1920).

The development of professional nursing

The increasing frequency of illness and the advances occurring in the outside world led the Sisters of Providence to evaluate their nursing role. The Sisters related three incidents as the final impetus for soliciting professional nursing service and a hospital for Desmarais. The transition from lay to professional nursing in Desmarais occurred from 1928 to 1929. The three incidents leading to this transition were the following.

On January 28, 1928, J. B. Bigstone arrived at the mission for care with severe frostbite after hunting in −60 degree weather (CSP, 1928). The second incident was the arrival of the Hudson's Bay manager's extremely ill wife at the mission for care. The final incident was the arrival of an accident victim at the mission for care. A Hudson's Bay employee, kicked by his horse arrived with a broken arm and lacerated face (CSP, 1928). To accommodate these patients the Sisters improvised a hospital ward in the community room of their residence. The severity of these cases convinced the Sisters they were no longer able to fulfill their nursing responsibilities without assistance. Consequently, the Sisters approached the Oblate Fathers with their recommendations for a hospital and professional nursing care. Construction of a temporary hospital began on July 26, 1928, and it took the form of a two-storey building of 28 by 30 feet. Unfortunately, professional nursing services were not acquired as easily as the hospital (CSP, 1928). Finally, on March 24, 1929, Sister Stephana, R.N., arrived from St. Paul hospital in Vancouver.

Health care services since introduction of professional nurses

The 1930s experienced greater access to the outside world. This access allowed for improvements in health facilities and the introduction of new services. On July 17, 1934, the Sisters moved into a new 20 bed hospital equipped with running water, an improved heating system and a small chapel. The introduction of preventive health care was experienced in 1935, when a public health care nurse and a physician arrived from Edmonton. Their purpose was to examine the school children. The children were all given a clean bill of health.

The trends of the 1930s continued in the 1940s with the Sisters as the sole resident providers of health care. They assumed a larger role in the delivery of babies in the 1940s. Prior to this time the Cree women delivered at home with the assistance of relatives and lay midwives. Surgery was introduced in Desmarais in 1947, when a nurse and physician arrived from Edmonton to perform 14 tonsillectomies. In 1948, patients requiring more specialized care were referred to the Charles Camsell Hospital (the majority of these patients had tuberculosis.)

In the 1950s, the Sisters worked towards upgrading facilities and health services. They remained isolated since the road to the community was unreliable. The most convenient and comfortable mode of transportation was the airplane (although this too was dependent on weather). In 1950, the Sisters received a premature neo-natal incubator from the Alberta Provincial Department of Public Health and Welfare. In 1957, the Oblates constructed a small electric plant for the mission, the first for Desmarais.

The 1960s witnessed many visitors from the outside and continued improvements in the community. In 1963, the hospital was renovated. In 1965, a dentist and two physicians arrived from the University of Alberta to practice for 10 weeks. Free dental services were provided to residents of Desmarais. Prior to this time the Sisters attended to dental care including extractions. The construction of a hospital in Slave Lake (136 kilometers from Desmarais) provided a closer referral center for patients in need of more specialized care, in the mid-sixties.

The seventies were difficult years for the Sisters. The hospital was incurring a large financial debt and admissions were increasing. The Sisters suffered from inadequate staffing in the earlier 1970s and solicited the aid of the Sisters of Providence in McLennan. In 1974, two meetings were held in Desmarais with local representatives and government officials, to discuss the future of health care in Desmarais. In October 1974, the hospital closed its doors to all in-patients while a new complex was being negotiated by the government. The hospital remained as a clinic and emergency room until completion of the new facility. In 1976, Desmarais began receiving regular medical visits three days a week.

The transition of health services from the Sisters of Providence to the government occurred in 1979 with the opening of the St. Martin Health Centre in Desmarais. The new facility provided no in-patient services. The administration of the centre was placed in the hands of the Slave Lake General Hospital. Despite the change in administration, the Sisters still provided registered nurses to staff the clinic.

Conclusion: implications for northern nursing

The Sisters' dedication to service was fundamental in establishing optimal nursing care in Desmarais. As the sisters devoted their life to service, they gave everything they could to their clients. The Sisters' devotion is commendable but is not free of consequences. In providing care, the Sisters fostered a dependency among the Woodlands Cree for their health care services. This dependency exists to this day but the nursing services of the Sisters have been greatly reduced.

The transition of health care responsibility for Desmarais from the church to the government has created a gap in services. The government services do not provide nurses to visit the infirm in their homes, as the Sisters did. In addition, there no longer is a hospital in the community. The result is that the residents who are accustomed to a dependent style of health care are required to take on a more independent role. This imposed independent focus can create a negative relationship between client and nurse. The nurse may view the client as inconsiderate and irresponsible when he/she arrives at the clinic at all hours of the day for treatment of a "cold". Yet, past experience may have taught the client to go to or send for the Sisters for every ailment. Therefore, it is appropriate for the client to go to the clinic at all hours.

To facilitate effective and culturally sensitive health care for the Woodlands Cree, further research is needed. The Woodlands Cree's perspective of health care needs, beliefs and values must be disclosed within its historical and cultural context. The research is needed if health care is more than the construction of a facility and the hiring of the personnel to staff it.

References

Auger, Josette (1986). Personal Communication, Desmarais Alberta, May 18.

Sisters of Providence (1901-1929) "Chronicles of the Sisters of Providence" St. Martin Mission, Desmarais.

Quesnelle, Sister Hortense (1976) Precis of the Chronicles of the St. Martin Mission, 1901-1974, unpublished paper.

Bibliography

Beach, Sister Eileen, Public Health Nurse, Desmarais, Alberta.

Cashman, T. (1966). Heritage of service: The history of nursing in Alberta. Edmonton: Alberta Association of Registered Nurses.

O'Connell, Sister Margaret, Registered Nurse 1978-1984, Desmarais Alberta.

Sisters of Providence. "Chronicles of the Sisters of Providence, 1901 to 1986," St. Martin Mission, Desmarais, Alberta.

Stewart, I. (1979). These were our yesterdays: A history of district nursing in Alberta. Manitoba: Friesen and Sons.

GROWTH PATTERN OF HIGH ARCTIC SPECIES OF *SAXIFRAGA TRICUSPIDATA* ROTTB. AND *S. OPPOSITIFOLIA* L., IGLOOLIK ISLAND, N.W.T.

Carey Ogilvie and Martin Lewis

Department of Biology, York University, North York, Ontario M3J 1P3

Level: C. Ogilvie, Master's

Abstract

A classification system was developed to age the ramet population within genets (plants) of *Saxifraga tricuspidata* Rottb. and *S. oppositifolia* L. Growth and demography on natural sites was measured; unenriched/undisturbed sites were compared to enriched/disturbed ones. Enriched/disturbed sites commonly supported colonies having (i) significantly larger (biomass) ramets in all age classes, (ii) a higher proportion of V_R (reproductive) ramets, (iii) ramets reproducing at a younger age (on unenriched/undisturbed sites ramets commonly become reproductive as V_{2R} or V_{3R} ramets whereas on enriched/disturbed sites ramets become reproductive primarily as V_{2R} ramets and even as V_{1R} ramets) and (iv) a faster turnover of ramets.

Plant growth and demography was also examined in field manipulated populations. Plants were subjected to fertilization, temperature amelioration and a combination of the two treatments. Application of N:P:Potash fertilizer alone had the greatest effect in proportion to dosage. Fertilized plants produced a greater number of first year (V_0) ramets and had significantly larger (dry weight) ramets in all age classes in the first year. There was no change in reproductive performance. Temperature amelioration produced no significant changes. A combination of both treatments resulted in a greater number of V_0 ramets and a significant increase in ramet size (biomass) of all age classes; however the effect of this combined treatment was less than fertilization alone.

Key words: Igloolik Island, growth pattern, *Saxifraga*, demography.

Résumé

Les auteurs décrivent les modes de développement des *Saxifraga oppositifolia* et des *S. tricuspidata* poussant dans l'île d'Igloolik (lat. 69°24' N., long. 81°49' 0.). Ces plantes ont une caractéristique qui leur est particulière: elles gardent leurs feuilles mortes. La disposition de celles-ci sur la tige permet d'élaborer des paramètres quantitatifs pour un groupe de tiges dans une plante individuelle. Les auteurs ont trouvé que le poids sec, l'état des organes de reproduction et le nombre de tiges dans chaque classe d'âge varient selon les différents habitats et au cours de la période végétative.

Ils ont entrepris des manipulations expérimentales pour déterminer quels sont le ou les facteurs limitant la croissance de ces plantes. Ils ont étudié les effets de températures plus élevées et de nutriments minéraux plus abondants. Pour ce faire, ils ont couvert les plantes avec des mini-abris afin de relever la température à l'intérieur, et ont ajouté de l'engrais chimique 20-20-20 (N-P-K) au sol, soit isolément, soit de concert avec la mise en place d'abris. Les résultats préliminaires de cette expérimentation montrent que le manque de nutriments minéraux est le principal facteur de milieu limitant la croissance de *S. oppositifolia* et *S. tricuspidata*.

Mots-clés: Île d'Igloolik, mode de développement, *Saxifraga*, peuplement.

Introduction

Most ecological studies have analyzed plant growth under various environmental or experimental conditions from either a physiological, or more recently, a demographic perspective. The physiological approach commonly takes the form of measuring primary production as change in dry weight although measurements of mineral nutrient concentration, caloric content, total nonstructural carbohydrates, etc. are also used (Haag, 1974; Abrahamson, 1979; Shaver and Chapin, 1980; Abrahamson and Caswell, 1982; Lechowicz and Shaver, 1982; Maessen *et al.*, 1983; Kummerov and Ellis, 1984; Grulke and Bliss, 1985; Jurik, 1985). Demographic analysis generally involves the measurement of parameters such as birth-rate, survivorship/mortality and fecundity of individual plants and/or shoots within the plant (White and Harper, 1970; Kays and Harper, 1974; Sarukhan, 1974; Callaghan and Collins, 1981; Sivertown, 1982). This mode of analysis has been applied to monocarpic plants (Law, 1981) and polycarpic perennial plants (Sarukhan and Harper, 1973; Schaffer, 1974; Mattheis *et al.*, 1976; Noble *et al.*, 1979; Maillette, 1982; Armstrong, 1984; Fetcher and Shaver, 1983) having a well-defined modular construction (i.e. those plants composed of repeated ramets of different ages). In fact, the ecological performance of perennial plants can be assessed at two levels. Changes can be followed in numbers of genetical individuals (genets) within the population or changes in the numbers of component parts (ramets) within each genetical individual (colony).

Growth (change in size) of the individual can be expressed as changes in biomass etc. or as changes in numbers of ramets within the colony (i.e. ramet birth, survivorship and recruitment to older age classes and reproductive state). By combining information from both approaches (i.e. changes in dry weight and numbers of ramets) a highly detailed, dynamic and more informative measurement of ecological performance can be attained.

This combined approach can provide valuable information on how a colonial plant responds to changing growing conditions. For example, in response to more favourable conditons an individual colony should exhibit both short and long term responses in both aspects of growth. In the short term (same growing season), there will be an increase in the biomass of individual ramets as well as a concurrent increase in the number of new ramet primordia initiating growth (i.e. increased vegetative birth).

The longer term responses may take three forms. The increased size of the individual ramets may continue beyond the first growing season (i.e. ramets of all ages get progressively larger). Additionally, the increase in the number of new ramets will inevitably lead to an increase in vegetative growth of the colony and in reproductive performance of the individual (genet). Providing there is no significant increase in mortality of vegetative ramets due to self-thinning associated with increased density, the new cohort of vegetative ramets will be recruited to the next age class at the start of the next growing season. Their parts, particularly leaves, may be larger, if overwintering primordia are enlarged by improved conditions for growth (the ramets of all age classes get progressively larger). The increased number and size of ramets, providing favourable conditions are maintained, will progress as a wave through successive age classes projecting the genet (colony) into an enhanced state of performance. This will be reinforced by the plant's natural tendency to conserve resources once sequestered. Finally, ramet primordia of perennial plants differentiate into reproductive structures when either (a) they are large enough (ripeness to flower; indeterminate) or (b) they have attained a certain predetermined age (determinate). In both cases, accelerated ramet production and vegetative growth will inevitably lead to a quantum leap in reproductive performance (sexual fecundity) as the new ramets attain the required size or age. If improved conditions foreshorten the time required to reach sexual maturity, because flowering/fruiting inevitably leads to death of the ramet, there will be faster turnover of modules within the colony. Interestingly, this dramatic increase in reproduction often involves a heavy investment in non-productive expendable structures (sinks, such as petals, sepals, flowering stalk, etc.) which may in turn diminish the relative allocation to vegetative growth (a delayed negative feedback on vegetative growth).

Sexual reproduction is particularly stressed by the short, cold growing season of tundra. It involves a complex series of morphogenetic changes in a definite temporal sequence. All stages in the sequence may be adversely affected by low temperatures and correlative phenomena such as the low frequency of pollinators. The period of time available in tundra environments for completion of the whole sequence may be one half or less than that in temperate latitudes. The ultimate goal of producing viable seed may only be reached in the most favourable year. The high risks have selected against the monocarpic habit; the probability of the sexual effort coinciding with a favourable year are too low. The polycarpic habit, the repetitive sexual effort by the genet, combined with a long reproductive life increases the probability of success (fitness), of the sexual effort coinciding with favourable times. Many polycarpic plants, including arctic ones, have evolved the colonial habit based on repeated modules (ramets); although a particular ramet within the colony (genet) is monocarpic, the genet persists through time and space by vegetative proliferation of new ramets (Tieszen *et al.*, 1981).

Saxifraga tricuspidata Rottb. and *S. oppositifolia* L. are colonial perennial plants in which individual ramets are monocarpic but function for more than one growing season. We developed a system for aging and classifying each individual ramet. Thus, demographic parameters can be generated for the various age classes of ramets contained within a single plant. Analyzing several plants from each habitat allows a comparison of the demography of the average colony as well as dry weight changes between sites. The existence of *S. tricuspidata* and *S. oppositifolia* populations exhibiting unusually prolific growth and reproductive rates at various isolated locations on Igloolik Island provided an opportunity to study the response of the plants to improved conditions.

Experimental field manipulations were also performed in order to assist in the interpretation of the unusually high performance of these isolated populations and secondarily to investigate whether the plants would respond to fertilization, temperature amelioration or a combination of the two manipulations.

Study sites and method

Study Sites

The study was conducted in the Canadian high arctic on Igloolik Island (69°24′N, 81°49′W). The 40-square mile island is underlain by Ordovician limestone and characteristically has shallow, poorly developed soils; individual sites can have soils ranging from highly organic peat to predominantly sand and gravel. Permafrost is present on all sites although thaw depth varies depending on the consistency and water content of the overlying soil and angle of slope. Many periglacial processes (such as polygons, nets, stripes, steps and solifluction) are presently active on the island (Lewis and Belya unpub.). Table 1 gives a general description of each site.

Monitoring of control populations of *S. tricuspidata* and *S. oppositifolia* at unenriched/undisturbed sites.

During the summer of 1985 *S. tricuspidata* (STLS) and *S. oppositifolia* (SOLS) populations were sampled from sites (one each) considered to be typical of the two species as described by Porsild (1957). In order to monitor any variation in STLS and SOLS ramet populations, ten whole plants were randomly harvested at approximately seven day intervals throughout the growing season. The ramets of each plant were classified according to the system outlined in Tables 2 and 3. Subsequently, the number of ramets in each category was tallied.

Comparison of populations from enriched/disturbed and control sites

During the summer of 1986 comparisons were made between control sites and sites where each species exhibited accelerated growth. To facilitate meaningful comparisons, each site was sampled at its point of maximum flower display. In this way we were assured of sampling each population at the same developmental stage.

S. tricuspidata was sampled on two control sites (STLS and STDB). Samples were also taken from two owl mounds (ST01 and ST02), a recently active owl nest (ST03), and two old Inuit hunting camps (STSS and STAV). These enriched sites supported plants exhibiting accelerated growth. In fact, growth was so prolific that individual plants could not be identified. Plant growth took the form of a continuous mat. Therefore sampling of these sites entailed harvesting a random 30 × 30 square cm area of the mat.

TABLE 1
General description of sites

Site	Relative Elevation	Slope and Aspect	Moisture Content	Exposure	Relative Nutrient Status	Soil type	Predominant Vegetation	General Comments
STLS	high	level	low	exposed	low	predominantly sand/gravel	*S. tricuspidata* *Dryas integrifolia* lichens	top of beach ridge
SOLS	inter-mediate	20° south	inter-mediate	sheltered	low	shallow mineral layer predominantly sand/gravel	*S. oppositifolia* *Salix arctica* *D. integrifolia*	middle of beach ridge
STDB and SODB	high	level	low	exposed	low	shallow organic layer predominantly sand/gravel	*S. tricuspidata* *S. oppositifolia* *D. integrifolia*	top of beach ridge
SOR1	high	60° south	low	sheltered	high	sand	*S. oppositifolia*	recently (<2 years) disturbed roadside
SOR2	high	level	low	moderately exposed	inter-mediate	sand/gravel	*S. oppositifolia* *Draba spp.*	older (>3 years) disturbed roadside
SODS	inter-mediate	10° south	low	sheltered	high	sand/clay	*S. oppositifolia* *Draba spp.*	recently (<2 years) disturbed construction site
ST01 and ST02	high	level	low	exposed	high	organic/ mineral	*S. tricuspidata* mosses	common perches for owls and the general bird population
ST03	high	level	low	exposed	very high	organic/ mineral	*S. tricuspidata* graminoids	an active owl nest in 1984
STSS	low	10° south	high	sheltered	high	shallow mineral predominantly sand/gravel	*S. tricuspidata* mosses	old Inuit hunting camp
STAV	high	15° south	low	moderately exposed	high	organic/ mineral	*S. tricuspidata* mosses	old Inuit hunting camp

TABLE 2
Ramet classification system for *S. tricuspidata*.
Criteria used in aging individual ramets.

Symbol	Description
V_0	Ramets having only green leaves (i.e. current year's growth). Ramet in first season but less than one year old.
V_1	Ramets having reddish leaves at the start of the season (last year's growth). As the season progresses a complement of green leaves are added. Ramet in second season but less than 2 years old.
V_2	Ramets having a set of dead, brown leaves in addition to a set of reddish leaves at the start of the season. As the season progresses a complement of green leaves are added. Ramet in third season but less than 3 years old.
V_3	Ramets having a set of dead, greyish-black leaves and a set of dead, brown leaves in addition to a set of reddish leaves at the start of the season. As the season progresses a complement of green leaves are added. Ramet in fourth season but less than 4 years old.

Ramets may become reproductive at any age. Such ramets are aged accordingly to the above system except they are classified as V_{1R}, V_2, V_{3R}). On control sites, V_{2R} and V_{3R} ramets are typical.

TABLE 3
Ramet classification system for *S. oppositifolia*.
Criteria used for aging individual ramets.

Symbol	Description
V_0	Ramets having only green leaves. Ramet in first season but less than one year old.
V_1	Ramets with one pair of golden leaves in addition to a set of green leaves. Ramet in second season but less than 2 years old.
V_2	Ramets having a set of dead brown leaves in addition to a set of green leaves. Ramet in third season but less than 3 years old.
V_3	Ramets with a set of dead, greyish-black leaves, a set of dead, brown leaves and a set of green leaves. Ramet in fourth season but less than 4 years old.

As with S. tricuspidata ramets, S. oppositifolia ramets may at any point become reproductive and are accordingly classified as either V_{1R}, V_{2R} or V_{3R}). Once again, V_{2R} and V_{3R} ramets predominate on control sites.

The collection of ramets was then classified and tallied. Ten individual ramets from each age class were then dried (68° for 24 hrs. to constant weight) and weighed.

Similarly, *S. oppositifolia* was sampled on two control sites (SOLS and SODB). In addition, samples were taken from two disturbed roadside sites (SOR1 and SOR2) and a construction site (SODS). At maximum flower display, ten plants were randomly harvested at each site. The ramets of each sample were subsequently classified and tallied. Dry weight was then recorded for five representative ramets from each age class for each plant.

Experimental field manipulations

Field manipulations were performed on the two species in an attempt to (a) identify whether increased temperature and/or mineral/nutrients were responsible for the accelerated growth rates observed on particular sites and (b) determine whether the plants could respond and if so, in what way they would respond within the same growing season. Directly after snowmelt the following field experiments were set up:

Symbol	Experiment
T	Ambient air temperatures were raised with small transparent tents placed over individual plants.
F_1	250 ml of 20:20:20 (N:P:Potash) fertilizer (diluted as instructed) was applied to the plants.
F_2	250 ml of 20:20:20 fertilizer was applied twice; once after snowmelt and again two weeks later.
TF_1	Transparent tents were placed over plants which had received 250 ml of 20:20:20 fertilizer.
C	Control plants, no manipulations.

Five plants were subjected to each manipulation. Equal amounts of distilled water were applied to T and C plants at the time fertilizer was applied to F_1 and F_2 plants. Rainfall was monitored throughout the experiment; equivalent amounts of distilled water were applied to those plants covered by tents.

These field experiments were run for two months after which plants were harvested, ramets classified and tallied. Dry weights were recorded for ten ramets from each age class for each plant.

Results and discussion

(a) Growth of both species under control (unenriched) conditions

The growth pattern is very similar in both species. Within the colonies (plants) of each species, ramets may survive for up to four growing seasons (V_3) providing they remain vegetative (Tables 4 and 5). The similarity in numbers of V_0 ramets late in the growing season and those of other age classes (i.e. V_1 to V_3) indicates very low mortality (self-thinning) of shoots once established within the colony (i.e. recruitment or survivorship is high between successive age classes).

TABLE 4
Distribution of *S. tricuspidata's* ramets throughout the growing season. n = 10 plants.

HARVEST DATE	AGE CLASSES					
	V_0	V_1	V_2	V_3	V_{2R}	V_{3R}
JUNE 3	0	91	67	94	22	30
JUNE 11	1	106	169	105	11	17
JUNE 18	40	134	282	154	37	21
JUNE 22	9	60	114	92	20	23
JUNE 29	85	60	230	133	17	14
JULY 6*	72	58	152	85	13	10
JULY 13	130	86	187	92	36	24
JULY 20	104	63	130	90	49	21
AUG. 5	104	75	171	169	15	20

* Maximum flower display.

TABLE 5
Distribution of *S. oppositifolia's* ramets throughout the growing season. n = 10 plants.

HARVEST DATE	AGE CLASSES					
	V_0	V_1	V_2	V_3	V_{2R}	V_{3R}
JUNE 4	0	237	663	251	91	16
JUNE 9	61	225	668	217	187	6
JUNE 16*	113	401	752	224	232	11
JUNE 24	322	293	815	231	86	59
JULY 1	126	103	687	243	24	60
JULY 8	75	81	884	274	20	132
JULY 15	273	217	624	142	123	112
JULY 22	724	392	902	441	38	102
AUG. 5	483	221	759	240	120	128

* Maximum flower display.

A proportion of ramets initiate floral primordia at the end of their second season (V_1) and flower at the beginning of their third season as V_{2R}; others (possibly the smaller ones) are delayed a year to flower as V_{3R} ramets while the remainder (V_3 ramets) never flower and die (death of the apical meristem) at the end of their fourth season. Reproductive ramets begin to die, as indicated by leaf discolouration, late in the season at about the time of seed set although some leaves may remain photosynthetic until the beginning of the next growing season.

Recruitment of new V_0 ramets begins one to two weeks after snowmelt and generaliy peaks at maximum flower display in both species (Tables 4 and 5). Most V_0 ramets appear in the axil of leaves on reproductive ramets. Thus, although differentiation of the apical meristem into floral structures prevents any further vegetative growth of the ramet, one or more of the lateral buds, in the form of V_0 ramets, will continue the growth of that particular major branch.

Analysis of this type has been useful in understanding graminoid growth patterns, especially the interaction between a genet's ramet population structure and growth of the colony (Mattheis *et al.* 1976; Noble *et al.* 1979). However, attempts to analyze herbaceous, dicotyledonous perennials in a similar manner have had limited success (Eriksson 1985).

TABLE 6
Ramet distribution in natural populations of *S. tricuspidata* at maximum flower display.

	AGE CLASS									
	Absolute Number (%)									
SITE	V_0	V_1	V_2	V_3	V_{1R}	V_{2R}	V_{3R}	TOT. V_R%	ABS. TOT.	% TOT.
STLS (CONTROL)	64(26.4)	54(22.3)	70(28.9)	21(8.7)	-	22(9.1)	11(4.5)	13.6	242	99.9
STDB (CONTROL)	145(33.6)	73(16.9)	87(20.2)	67(15.5)	-	20(4.6)	39(9.0)	13.6	431	99.8
STSS	89(33.7)	65(24.6)	46(17.4)	2(0.8)	1(0.4)	59(22.3)	2(0.8)	23.5	264	100
STO1	63(29.6)	78(36.6)	12(5.6)	5(2.3)	10(4.7)	45(21.1)	-	25.8	213	99.9
STO2	79(25.0)	120(38.0)	47(14.9)	6(1.9)	4(1.3)	60(19.0)	-	20.3	316	100.1
STO3	216(48.0)	171(38.0)	26(5.8)	-	4(0.9)	33(7.3)	-	8.2	450	100
STAV	118(33.1)	65(18.3)	106(29.8)	-	-	67(18.8)	-	18.8	356	100

TABLE 7
Ramet distribution in natural populations of *S. oppositifolia* at maximum flower display.

	AGE CLASS									
	Absolute Number (%)									
SITE	V_0	V_1	V_2	V_3	V_{1R}	V_{2R}	V_{3R}	TOT. V_R%	ABS. TOT.	% TOT.
SOLS (CONTROL)	47(3.5)	182(13.6)	752(56.2)	192(14.3)	-	57(4.3)	108(8.1)	12.4	1338	100
SODB (CONTROL)	47(6.9)	118(17.2)	296(43.1)	180(26.2)	-	-	45(6.6)	6.6	686	100
SODS	429(29.7)	123(8.5)	584(40.4)	10(0.7)	3(0.2)	255(17.7)	40(2.8)	20.5	1444	100
SOR1	794(33.9)	326(13.9)	757(32.2)	28(1.2)	9(0.4)	357(15.2)	71(3.0)	18.2	2342	99.9
SOR2	294(19.1)	307(19.9)	619(40.2)	143(9.3)	-	50(3.2)	128(8.3)	11.5	1541	100

(b) Comparison of growth in both species under various natural conditions (i.e. control and enriched sites)

(i) In general, the relative proportions of age classes (V_0–V_2) within colonies remain similar under a variety of natural conditions including control and enriched sites (Tables 6 and 7). Vegetative birth rates and survivorship between age classes have equilibrated or are beginning to equilibrate at similar levels.

(ii) At favourable sites there is a striking shift, in both species, to flowering at a younger age as V_{2R} ramets and to a smaller extent even as V_{1R} ramets (Tables 6 and 7). This shift is particularly marked in *S. tricuspidata* with a consequent reduction in the proportion of V_{3R} ramets. Each ramet has a greater probability of becoming reproductive under more favourable conditions as reflected in the significant reduction in the proportion of or absence of V_3 vegetative ramets and in the increased total percentage of reproductive ramets. This indicates a faster turnover of ramets within a colony. Noble *et al.* (1979) report a similar increase in the turnover rate of ramets in fertilized *Carex arenaria*.

(iii) From Tables 8 and 9, both species' vegetative ramets were significantly larger in all age classes at most sites. This was determined by performing (a) Kruskal-Wallis test (weights of ramets found to be not equal on the various sites) followed by a nonparametric comparison on *S. tricuspidata* ramet weights at different sites and (b) ANOVA — Model I (mean weights of ramets found not to be equal on the various sites) followed by Dunnett's test on *S. oppositifolia* mean ramet weights. Nonparametric tests were performed on *S. tricuspidata* data because of the small sample size (n = 10) whereas parametric tests were performed on *S. oppositifolia* data (n = 50).

TABLE 8
Means and rank sums of ramet weights in natural populations of *S. tricuspidata* (n = 10 ramets for each site and age class).

AGE CLASSES	SITES							
V_0	STLS	STDB	STO2	STSS	STO1	STAV	STO3	(site)
	3.5	3.5	4.9	7.5	9.3	10.4	20.8	(mean-mg)
	125.5	132.0	213.0	369.5	468.0	522.0	655.0	(rank sum)
V_1	STLS	STDB	STO1	STSS	STAV	STO2	STO3	
	9.0	13.4	19.9	30.4	33.4	39.3	98.1	
	82.0	149.5	259.0	396.5	404.5	474.5	630.0	
V_2	STLS	STO1	STDB	STO2	STSS	STAV	STO3	
	23.5	24.8	31.1	58.7	71.4	74.9	84.9	
	129.5	148.5	207.0	411.0	492.0	517.0	557.0	

Nonparametric multiple comparisons

H_0: Ramet weights are the same

H_A: Ramet weights are not the same

$P < .05$

TABLE 9
Mean ramet weights (mg) in natural populations of *S. oppositifolia* (n = 50 ramets for each site and age class).

AGE CLASSES	SITES					
V_0	SODB	SOLS	SOR2	SOR1	SODS	(site)
	0.29	0.39	1.03	1.47	1.86	(mean-mg)
V_1	SODB	SOLS	SOR2	SOR1	SODS	
	0.79	1.00	1.83	2.07	2.36	
V_2	SODB	SOLS	SOR2	SOR1	SODS	
	1.78	1.97	2.87	5.32	5.51	
V_3	SODB	SOLS	SOR2	SOR1	SODS	
	1.89	2.85	3.99	4.68	7.77	

Dunnett's test

H_0: $u_c \geq u_x$

H_A: $u_c < u_x$

$P < .05$

TABLE 10
Ramet distribution in experimental populations of *S. tricuspidata*. Absolute numbers (%).

	AGE CLASSES							
MANIPULATION	V_0	V_1	V_2	V_3	V_{2R}	V_{3R}	ABS. TOT.	% TOT.
C	117(23.8)	110(22.4)	118(24.0)	99(20.2)	33(6.7)	14(2.9)	491	100
T	43(11.2)	41(10.7)	107(27.9)	159(41.4)	6(1.6)	28(7.3)	384	100.1
TF_1	231(28.1)	107(13.0)	254(30.9)	182(22.2)	31(3.8)	16(1.9)	821	99.9
F_1	211(37.3)	89(15.7)	129(22.8)	101(17.8)	30(5.3)	6(1.1)	566	100
F_2	468(38.8)	256(21.3)	319(26.5)	106(8.8)	38(3.2)	16(1.3))	1203	100

TABLE 11
Ramet distribution in experimental populations of *S. oppositifolia*. Absolute numbers (%).

	AGE CLASSES							
MANIPULATION	V_0	V_1	V_2	V_3	V_{2R}	V_{3R}	ABS. TOT.	% TOT.
C	175(19.0)	127(13.8)	523(56.7)	86(9.3)	4(0.4)	8(0.9)	923	100.1
T	266(20.6)	157(12.2)	649(50.2)	170(13.2)	27(2.1)	23(1.8)	1292	100.1
TF_1	901(41.7)	377(17.4)	701(32.4)	181(8.4)	0	1(0.1)	2161	100
F_1	925(36.2)	360(14.1)	1121(43.9)	138(5.4)	3(0.1)	5(0.2)	2552	99.9
F_2	830(49.8)	190(11.4)	601(36.1)	36(2.2)	8(0.5)	2(0.1))	1667	100.1

(c) Summary of natural sites

Presumably at some indeterminate time in the past certain sites were enriched by human intervention (i.e. STSS, STAV, SOR1, SOR2 and SODS) or non-human causes (i.e. ST01, ST02 and ST03). This invoked a pulsed response of the type described in the introduction initially involving an enhanced vegetative birth rate (proportionately more V_0) and higher growth rates of individual ramets (bigger ramets). As the pulse progresses through successive age classes the colony is projected into an elevated equilibrium state in which relative proportions of age classes do not differ significantly from controls but individual ramets within the colony complete their life cycle earlier (i.e. more rapid turnover and higher reproductive rate but lower survivorship of older ramets; V_2 and V_3). A non-equilibrium transitional phase in this process (pulse) can be seen at ST03 (recently enriched by nesting) where we find a disproportionately high number of V_0 for an equilibrium condition and a smaller proportion of reproductive ramets than expected. Similar transitional examples for *S. oppositifolia* are found at SOR1 (a recent disturbed roadside) and SODS (a recent disturbed construction site).

(d) Growth of both species under experimental (manipulated) field conditions

This series of experiments was undertaken to determine the nature and onset of short term responses to improved field conditions. The effects of temperature amelioration and nutrient enrichment were tested separately and in combination. It was hoped that this would distinguish the separate effects of temperature and nutrients in accounting for the observed responses at favourable sites (section b).

Both species responded significantly to nutrient addition (both dosage treatments) but there is no discernable effect of temperature amelioration (Tables 10, 11, 12 and 13). Higher nutrient dosage (F_2) results in greater growth. This is reflected in a much higher proportion of V_0 ramets and a very significant increase in the dry weight of ramets of all age classes.

As expected in short term pulsing, there is no noticeable change in reproductive performance. Responses in sexual differentiation to improved conditions will take one full growing season, since flowering primordia are intitiated in the season prior to flowering. Although not investigated, it is likely that the proportion of differentiated primordia at the end of the season was higher in treatments T, F_1, F_2 and TF_1, particularly in V_1 ramets.

A number of studies have shown arctic and most temperate plants will respond to fertilization (Haag, 1974; Austin and Austin, 1980; Shaver and Chapin, 1980; Lechowicz and Shaver, 1982; Gartner *et al.*, 1983; Shaver *et al.*, 1986), especially nitrogen and phosphorus, by increasing primary production and mineral nutrient content. Chapin and Shaver (1985) looked at a number of arctic species under similar experimental setups as in this study. They reported variable response to fertilization and greenhouse field manipulations, some species increased ramet (shoot) production whilst others showed no response. However, they did not consider changes in the ramet population structure of any of the species examined. Only Noble *et al.* 1979 looked at changes in plant growth (to fertilization) by measuring changes in ramet size and population structure. In accordance with our findings, they found an initial pulse in fertilized *Carex arenaria's* ramet production.

TABLE 12
Mean ramet weight (mg) in experimental populations of *S. tricuspidata*
(n = 50 ramets for each manipulation and age class).

	MANIPULATION					
AGE CLASSES	T	C	F_1	TF_1	F_2	(manipulation)
V_0	3.18	6.68	9.92	12.68	16.97	(mean-mg)
	C	T	TF_1	F_1	F_2	
V_1	15.87	19.72	25.5	26.89	44.17	
	T	C	F_1	TF_1	F_2	
V_2	30.31	35.83	39.12	55.43	74.06	
	C	T	TF_1	F_1	F_2	
V_3	25.56	34.16	39.58	42.99	58.2	

Dunnett's test

H_0: $u_c \geq u_x$

H_A: $u_c < u_x$

$P < .05$

TABLE 13
Mean ramet weight (mg) in experimental populations of *S. oppositifolia*.
(n = 50 ramets for each manipulation and age class).

	MANIPULATION					
AGE CLASSES	C	T	TF_1	F_1	F_2	(manipulation)
V_0	0.93	1.02	1.32	1.61	2.19	(mean-mg)
	C	T	TF_1	F_1	F_2	
V_1	1.44	1.57	2.12	2.30	2.73	
	C	TF_1	T	F_1	F_2	
V_2	3.18	4.69	4.77	5.55	5.88	
	C	T	TF_1	F_1	F_2	
V_3	3.21	4.16	5.67	6.19	6.57	

Dunnett's test

H_0: $u_c \geq u_x$

H_A: $u_c < u_x$

$P < .05$

References

Abrahamson, W.G. 1979. A comment on vegetative and seed reproduction in plants. Evolution 33:517-519.

Abrahamson, W.G., and H. Caswell. 1982. On the comparative allocation of biomass, energy, and nutrients in plants. Ecology 63:982-991.

Armstrong, R.A. 1984. On the quantitative theory of reproductive effort in clonal plants: Refinements of theory, with evidence from golden rods and May apples. Oecologia 63:410-417.

Austin, M.P., and B.O. Austin. 1980. Behavior of experimental plant communities along a nutrient gradient. Journal of Ecology 68:891-918.

Callaghan, T.V., and N.J. Collins. 1981 Life cycles, population dynamics and the growth of tundra plants. In Bliss, L.C., Heal, G.W., and J.J. Moore (eds.), Tundra Ecosystems: a Comparative Analysis. Cambridge University Press, N.Y.

Chapin, F.S. III and G.R. Shaver. 1985. Individualistic growth response of tundra plant species to environmental manipulations in the field. Ecology 66:564-576.

Erikson, O. 1985. Reproduction and clonal growth in *Potentilla anserina* L. (Rosaceae): the relation between growth form and dry weight allocation. Oecologia 66:378-380.

Fetcher, N., and G.R. Shaver. 1983. Life histories of tillers of *Eriophorum vaginatum* in relation to tundra disturbance. Journal of Ecology 71:131-147.

Grulke, N.E., and L.C. Bliss. 1985. Growth forms, carbon allocation, and reproductive patterns of high arctic Saxifrages. Arctic and Alpine Research 17:241-250.

Haag, R.W. 1974. Nutrient limitations to plant production in two tundra communities. Canadian Journal of Botany 52:103-116.

Jurik, R.W. 1983. Reproductive effort and CO_2 dynamics of wild strawberry population. Ecology 64:1329-1342.

Kays, S., and J.L. Harper. 1974. The regulation of plant and tiller density in a grass sward. Journal of Ecology 62:97-105.

Kummerov, J. and B.A. Ellis. 1984. Temperature effect on biomass production and root/shoot biomass ratios in two arctic sedges under controlled environmental conditions. Canadian Journal of Botany 62:2150-2153.

Law, R. 1981. The dynamics of a colonizing population of *Poa annua*. Ecology 62:1267-1277.

Lechowicz, M.J., and G.R. Shaver. 1982. A multivariate approach to the analysis of factorial fertilization experiments in Alaskan arctic tundra. Ecology 63:1029-1038.

Lewis, M.C., and D. Belya. 1979. The vegetation of Igloolik Island. unpublished.

Maessen, O., Freedman, B., Nams, M.L.N., and J. Svoboda. 1983. Resource allocation in high arctic vascular plants of differing growth form. Canadian Journal of Botany 61:1680-1691.

Maillette, L. 1982. Structural dynamics of Silver Birch. Applied Ecology 19:203-218.

Mattheis, P.J., Tieszen, L.L., and M.C. Lewis. 1976. Responses of *Dupantia fisheri* to simulated lemming grazing in an Alaskan arctic tundra. Annals of Botany 40:179-197.

Noble, J.C., Bell, A.D., and J.L. Harper. 1979. The population biology of plants with clonal growth. I. The morphology and structural demography of *Carex arenaria*. Journal of Ecology 67:983-1008.

Porsild, A.E. 1964. Illustrated flora of the Canadian arctic archipelago. National Museum of Canada. Bulletin 146.

Sarukhan, J. 1974. Studies on plant demography: *Ranunculus repens* L., *R. bulbosus* L. and *R. acris* L. II. Reproductive strategies and seed population dynamics. Journal of Ecology 62:151-177.

Sarukhan, J., and J.L. Harper. 1973. Studies on plant demography: *Ranunculus repens* L., *R. bulbosus* L. and *R. acris* L. I. Population flux and survivorship. Journal of Ecology 61:675-716.

Schaffer, W.M. 1974. The evolution of optimal reproductive strategies: The effects of age structure. Ecology 55:291-303.

Shaver, G.R., and F.S. Chapin, III. 1980. Response to fertilization by various plant growth forms in an Alaskan tundra: nutrient accumulation and growth. Ecology 61:662-675.

Shaver, G.R., Chapin, F.S., III, and B.L. Gartner. 1986. Factors limiting seasonal growth and peak biomass accumulation in *Eriophorum vaginatum* in Alaskan tussock tundra. Journal of Ecology 74:257-278.

Silvertown, J.W. 1982. Introduction to Plant Population Ecology. Longman Pub., N.Y.

Tieszen, L.L., Lewis, M.C., Miller, P.C., Mayo, J., Chapin, F.S., III, and W. Oechel. 1981. An analysis of processes of primary production in tundra growth forms. In Bliss, L.C., Heal, O.W., and J.J. Moore (eds.). Tundra Ecosystems: a Comparative Analysis. Cambridge University Press, N.Y.

White, J., and J.L. Harper. 1970. Correlated changes in plant size and number in plant populations. Journal of Ecology 58:467-485.

ENVIRONMENTAL ASSESSMENT MECHANISMS IN THE YUKON TERRITORY: A REVIEW OF LEGISLATIVE AND ADMINISTRATIVE PROCEDURES

Donna Pawlowski

Faculty of Environmental Studies, York University, North York, Ontario M3J 1P3

Level: Master's

Abstract

The Yukon Territory does not have a specific framework for an environmental assessment process, only a number of prohibition and approval systems for environmental protection and some limited assessment procedures. Three major review and approval systems in Yukon that contain assessment procedures are critiqued (the federal Environmental Assessment and Review Process (EARP), the water use, and the land use permitting and approval systems). These are found to be lacking, unable to deal effectively with issues relating to environmental protection and natural resource development, and do not suggest a comprehensive evaluation process that explicitly considers the social, cultural, economic and ecological effects of an undertaking prior to decision-making. An argument is made in support of a regional environmental assessment mechanism for the Yukon Territory.

Key words: Yukon, environmental assessment, Federal Environmental Assessment and Review Process (EARP), Water Board, Territorial Land Use Regulations.

Résumé

On a proposé le texte préliminaire d'un Accord sur le Plan d'aménagement du territoire nordique (NLUP) pour le Yukon.

L'un de ses objectifs est: de contribuer à la mise en évidence et à la résolution des problèmes posés par l'exploitation des ressources renouvelables et épuisables, et des questions sociales, culturelles et environnementales associées.

Cependant, le texte préliminaire de l'Accord ne précise pas comment on identifiera les problèmes et comment on les résoudra, ni comment on considérera les questions sociales, culturelles et environnementales dans le cadre de l'aménagement du territoire nordique.

La prospective d'environnement est définie comme le processus d'évaluation des conséquences, pour le milieu, d'une activité nouvelle ou d'une utilisation particulière du terrain, avant toute décision de mise en oeuvre de cette activité ou utilisation. La présentation graphique traite du rôle de la prospective d'environnement en matière d'aménagement nordique. Plus précisément, le présentateur décrit les moyens par lesquels les plans élaborés dans le cadre du NLUP seront soumis au processus de prospective d'environnement et d'analyse subséquente, compte tenu des mécanismes de protection de l'environnement et d'analyse des prospectives existant au Yukon.

Mots-clés: Aménagement du territoire nordique, Yukon, prospective d'environnement.

Introduction

Environmental assessment in Canada is seen as a mechanism for pre-action evaluation to determine the environmental consequences of an activity prior to decision making. An action is any undertaking, activity, project, programme, plan, development, or process that is induced or produced by man.

A variety of frameworks for environmental assessment exist in all of the provinces in Canada (figure 1). The Yukon Territory does not have a specific framework for an environmental assessment process. There are a number of environmental protection requirements in Yukon (prohibition and approval systems and some limited assessment procedures) that may constitute parts of an adequate regional environmental assessment process, however these are fragmented and compartmentalized. They do not suggest a comprehensive evaluation process that explicitly considers the social, cultural, economic and environmental effects of an undertaking prior to decision-making.

In the first half of this paper the purpose and rationale for environmental assessment will be discussed and an overview of a general environmental assessment process presented. In the second half of the paper existing environmental protection requirements in Yukon will be reviewed, weaknesses and deficiencies identified, and an argument presented in support of a regional environmental assessment process for Yukon.

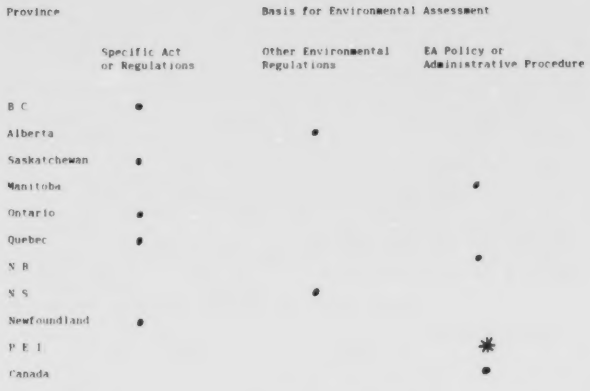
Environmental Assessment

Rationale and Definition

Over the past 20 years there has been strong pressure for governments to incorporate "environmental" considerations into decision-making. A need was seen for government decision-making mechanisms that reflected public sensitivity to the shortcomings of the traditional way in which major development decisions were made. These shortcomings centred on the failure of traditional economic analyses (for example, cost benefit analysis) to recognize many low visibility, difficult to quantify "public" costs and "free" public resources (air, land, water) (Emond, 1978).

This pressure forced the development of formal mechanisms of environmental assessment. Mechanisms of environmental assessment aim to identify and evaluate all potential environmental effects and insure that both the proponent and the approving body give due consideration to the means of avoiding or mitigating adverse environmental effects prior to the decision as to whether an undertaking should proceed or not.

Figure 1
Provincial Approaches to Environmental Assessment



The relevant statutory and non-statutory documents are as follows:

British Columbia — Environmental Assessment Act, S.B.C. 1981, c. 14. Alberta — Land Surface Conservation and Reclamation Act, S.A. 1973, c. 34 as amended. Saskatchewan — The Environmental Assessment Act, S.S. 1980, C. E-10.1. Manitoba — pursuant to Cabinet policy. Ontario — Environmental Assessment Act, 1975, R.S.O. 1980, c. 140. Quebec — Environmental Quality Act, S. Q. 1979, c. Q-2 Div. IV-1. New Brunswick — pursuant to Cabinet policy. Nova Scotia — Environmental Protection Act, S.N.S. 1973, c. 6 as amended. Newfoundland — Environmental Assessment Act, 1980, S. Nfld. 1980 c. 3. *Prince Edward Island — not practised on a comprehensive basis but government departments and agencies are expected to prepare EIS's under guidance of the Environmental Control Commission. Canada — Revised Guide to the Federal Environmental Assessment Review Process, 1979, FEARO, Ottawa.

Mechanisms of environmental assessment are seen as administrative tools to be used in project and process planning. In this respect environmental assessment is an information gathering process — an institutional process to identify the environmental, social, cultural and economic costs of an undertaking and to sensitize the proponent of the undertaking, the government and the people affected to these external costs of economic development.

However, environmental assessment is also seen as a comprehensive decision-making mechanism for government. A mechanism that provides a planning framework for the evaluation of the net environmental effects of an undertaking or of a broad range of alternatives to the undertaking. In this sense environmental assessment represents a shift in decision-making mechanisms. It is an attempt to leave the ultimate decision about an activity to someone other than the proponent, someone who is more attuned to the total costs and less sensitive to the economic benefits of the undertaking (Emond, 1978).

One of the results of this difference in interpretation of the concept, is that no common operational definition of EA has emerged beyond the procedural direction and general technical requirements provided by government guidelines, policies or legislation (Beanlands and Duinker, 1983).

Procedural model

Specific legislative or technical requirements for EA vary with jurisdiction, yet the procedural direction is fairly consistent. The activity undergoes a preliminary scrutiny to determine in broad terms, those aspects of the environment that may be affected by the activity. Specific changes to the environment are then forecast (predicted) and their significance or relative importance assessed. All of the positive and negative changes (impacts) are considered in the final evaluation, and a decision is made (based on previously determined criteria) as to whether the activity should proceed or not.

Activities are initially screened or pre-assessed by the proponent. Small, routine projects with no substantial or significant impacts are directed into a different assessment stream then those activities which may have significant adverse environmental impacts. The latter activities are directed to an administrative agency for a thorough and structured review. An environmental assessment is performed and prepared by the proponent of the activity. An environmental impact statement (EIS) is the administrative tool generally used for this second screening phase. An EIS includes:

- a description of the activity or undertaking,
- a description of the environment without the activity,
- an analysis and prediction of the effects of the activity on the environment,
- presentation of mitigative measures,
- and a statement of residual adverse effects.

The EIS is co-ordinated and reviewed by the lead agency or a review board or panel.

The public is involved in the process through specific public information and participation programmes that are established by the proponent; by invitation to review the EIS document; or by intervening at public hearings or meetings.

The co-ordinating agency brings together the EIS, the information brought forward by the public, and information from any interdepartmental government reviews for a formal review. The review is conducted by an independent panel, review board or the lead agency. The proposed activity is then recommended as acceptable or not, a political decision is made as to whether the activity should proceed or not, and terms are imposed as conditions of approval for ultimate regulation of the activity.

The scope of assessment

Initially most guidelines for assessments in Canada emphasized bio-physical phenomena. EA was considered another administrative mechanism for environmental protection. However, since the early 1970's, as social and economic considerations have been accorded equal importance, EA has grown into more of an environmental and socio-economic planning exercise, the proposed activity providing a geographical focus (Beanlands and Duinker, 1983). EA has become a formal review mechanism and evaluation framework for the net environmental effects associated with an undertaking. It gives explicit consideration to the social, cultural, economic, ecological and technical effects of an undertaking; it allows public review of this information and seeks public input; it provides for a net evaluation of the environmental effects of the undertaking by an independent body which in turn passes its recommendations on to a decision-making authority, and ideally the recommendations of the assessment process are enforced, that is implemented and monitored as part of the terms and conditions of approval. In the ideal case, environmental assessment:

- provides a means by which public costs and externalities may be identified and incorporated into the traditional economic evaluation of an action;
- allows the incorporation of societal values and community concerns in decision-making,
- forces a full and frank examination of the political, economic, social, cultural and ecological issues surrounding an undertaking,
- offers a formal guarantee to the public, the proponent and government that certain activities will not proceed unless the activity stands up to scrutiny about the potential consequences of proceeding.

Review and approval mechanisms in Yukon

No less than 20 different pieces of legislation (Acts of Parliament or sets of regulations), as well as a number of special cabinet directives set out the rules governing development activities in the North. (See Appendix 1 for a review of the legislation). Most of this legislation sets out specific environmental protection requirements. Mechanisms for environmental assessment are seen as distinct from mechanisms of environmental protection. Environmental protection mechanisms generally are statutes or sets of regulations that contain licensing or approval requirements and outright prohibition of potentially environmentally damaging activities (Lucas and Hunt, 1981). Each statute or regulation is intended to deal with a particular type of environmental damage or environmentally harmful activity. For example, the Arctic Waters Pollution Prevention Act provides a detailed approval system designed to prevent pollution of Arctic waters by means of controls on discharge of waste into Arctic waters.

This section is concerned with the legislation and administrative processes now in place in Yukon that are aimed at reviewing and assessing various northern activities (excluding offshore activities) as part of the approval system. There are three major review and approval systems in Yukon. The Federal Environmental Assessment and Review Process (which reviews major development proposals), the northern water use, and the northern land use permitting and approval systems (which review regional and local scale activities) will be reviewed and critiqued.

Federal Environmental Assessment and Review Process

Structure and function

The federal government policy on environmental assessment requires that the environmental implications of government actions be considered prior to taking irrevocable decisions and as early as possible in the planning process. The Environmental Assessment and Review Process (EARP) is the mechanism by which the federal government's policy on environmental assessment was established (1973). It has since been adjusted (1977), reaffirmed (1979) and improved (1984).

EARP is a two-stage process for screening and reviewing the environmental impact of proposals initiated by federal departments, or which are federally assisted (e.g. through provision of lands or financing). Since Yukon is primarily an area of federal responsibility, and 97% of the lands in Yukon are administered by the Federal Government, the EARP process is significant in the planning, design and implementation of major projects in Yukon.

If the initiating department's own screening assessment indicates that there are potentially significant environmental effects from the proposed project, the proposal is given a full review under the direction of the Federal Environmental Assessment and Review Office (FEARO). Where the significance of these effects is unknown, an Initial Environmental Evaluation (IEE) is conducted by the proponent under EARP guidelines. This can lead to the project proceeding, subject to mitigating measures and FEARO scrutiny, or to a full blown EARP review.

A project submitted to FEARO for review under EARP is referred to an independent Environmental Assessment Panel for public review. This body, with technical assistance from FEARO and public comment, develops guidelines for an Environmental Impact Statement (EIS) which is then prepared by the initiator and submitted for review by government and the public.

Review of the EIS is followed by public hearings in the area affected. Recommendations as to dispositon of the proposal are then prepared, focussing on mitigation or prevention of adverse effects, and are submitted to the Ministers of the Environment and of the initiating department for disposition.

Decisions on the extent to which a Panel's recommendations are to become a government requirement, are made by the initiating department, prior to a proposal's implementation.

Critique

The principles of EARP have gained widespread acceptance, an indication of the "need" for environmental assessment processes. However there are a number of shortcomings to the process — paricularly with respect to its application. These criticisms have been fully documented elsewhere (Emond, 1983; FEARO, 1983; Rees, 1981; Boothroyd and Rees, 1984) and mainly focus on the problems and difficulties inherent in any environmental assessment process (the increasingly broad scope, unclear information requirements, undefined and uncertain time frames, lack of intervenor funding, etc.). Key issues that arise with respect to EARP and Canada's North are listed herewith.

(1) Inconsistent policies in the North regarding development and environmental protection, and the lack of any form of regional land and resource planning have resulted in an ever broadening range of interests, concerns and objectives being "piggybacked" onto the environmental assessment process (Beanlands and Duinker, 1983). EARP is forced to act as a regional planning body, a forum to resolve technical disputes, a rational means of facilitating government approval of a proposed project, and a mechanism to stop, delay or restrict the project. Thus EARP has become all things for all people because it is the only game in town (Emond, 1983)

(2) The application of EARP across the government is limited. Crown corporations and regulatory agencies need abide by the Regulations only if (1) it is in their corporate policy to do so and/or (2) there is no legal impediment or duplication from application of the Guidelines (Order-in-Council, 1984). Screening systems are found to be *ad hoc* and inconsistent, lacking in internal policy direction, without proper direction, and limited to capital projects (FEARO, 1983). However the inconsistencies may change with the recently published Initial Assessment Guide (FEARO, 1986) that provides guidelines to federal departments and agencies in the preparation of procedures for screening and initial assessment.

(3) There is no standard procedure for the disposition of panel recommendations. Neither a panel nor the public can be sure that they will be informed of the decisions taken in response to a review, or the extent to which decisions are incorporated into project design and construction. In this sense EARP is incomplete, with no evident connection to the implementation phase (FEARO, 1983).

(4) Only a small proportion of the proposals subjected to screening and initial evaluation go through the full review process; approximately 1 in 1000 projects screened go to full review and only 5 projects have ever been reviewed in Yukon (FEARO, 1986). The full review process is really reserved for major development projects such as the Beaufort Sea Hydro-Carbon proposal. Thus the cumulative effects of several minor government projects go unexamined.

In summary the EARP process, although thorough when it is in effect, is limited because it applies only to major projects with federal involvement. It is not consistently applied across government departments and agencies, is not applied at all to private sector proposals. The system is also ineffective and inefficient as an assessment mechanism because the results of the assessments are not necessarily implemented.

The water use permitting and approval system

Structure and function

The Northern Inland Waters Act (NIWA) (established in 1970 and amended in 1977, 1982 and 1984), the Northern Inland Waters Regulations (NIWR) and the Yukon Territory Water Board (YTWB) are the basic components of the water use approval system in Yukon. The Regulations establish water management areas, classify uses of water, provide survey and design requirements, and set out water use fees. The Water Board is meant to provide for the conservation, development and utilization of the water resources of the Yukon Territory (and N.W.T.) in a manner that will provide the optimum benefit therefrom for all Canadians and for the residents of the Yukon Territory (and N.W.T.) in particular.

The Water Board may issue licences authorizing an applicant to use waters, at the times and in the manner described by the regulations, in association with the operation of a particular undertaking described in the licence. The Act allows the Water Board to attach any conditions that it considers

appropriate to any licence issued but cannot contravene the Canada Water Act, or the Fisheries Act (which protects fish and their habitat from physical interference and pollution.)

An application for a water licence goes to the Yukon Territory Water Board. The application includes a specific water use information sheet that details the location and expected life of the activity, the source and rate of water use, method of wastewater treatment, physiography of the area (from the ground surface downward), limitation to water supply, etc.

The application is reviewed by technical advisors to the Water Board, and is circulated to an interdepartmental review committee for comment and direction (Health and Welfare Canada, Environment Protection Service of Environment Canada, Fisheries and Oceans, and the Water Resources Branch of DIAND). At the same time public notice of the application is made inviting interested parties to submit briefs at a public hearing. The notice describes the nature and extent of the activity and establishes the time and place for a public hearing. If no interventions are filed, the Board usually cancels the hearings. If submissions are received, a public hearing is held.

After the hearings, the Board reviews the application in light of the arguments presented. The Board has had to deny licences for a variety of reasons including possible conflicts with existing users, inadequate investigation by the applicant and failure to meet basic water quality standards for effluent discharge (Pearse, 1985). However, the Board usually sets appropriate terms and conditions for the activity, and sends a draft licence to the Minister (DIAND) for final approval. The Minister has never denied a licence submitted by the Board.

Critique of the review process

There are a number of problems with the water use licensing process in Yukon that severely limit it in an environmental assessment function.

(1) There is no specific requirement for environmental impact studies — only engineering survey and design information. The regulations state that the Water Board shall require such information and studies as will enable it to evaluate any qualitative or quantitative effects of the proposed use on the water management area. However this requirement is open to interpretation. The nature, scope and degree of environmental impact studies will depend on the position the board itself takes and on public demands.

(2) Most minor uses of water are exempt from the licensing requirement and any form of regulation. Many water users must judge for themselves whether they need a licence. The YTWB does ask that all water users file an application so that the Board can decide whether or not a licence is required. However not all exempt water users will do so. Thus there is no mechanism in place to monitor and evaluate the cumulative impacts of the changes associated with minor water uses and there is no mechanism to provide the Board with complete information about all water uses in the territory.

(3) The licensing system does not deal directly with instream water uses (navigational, recreational, aesthetic, environmental). The Board has no basis to consider a wide range of values and interests and may therefore neglect these water uses in allocation and decision-making. This is important because the lifestyles of northern residents, particularly native people, depend heavily on natural waterways and the fish and wildlife they support.

(4) Placer mining activities are licensed under expedited procedures. These procedures allow applications to be processed without a public hearing. Or, where hearings are held, statements are limited to 10 minutes each and no cross examination allowed. This effectively limits the review of placer mining activities to technical considerations only. This is a serious limitation on the approval system because placer mining is one of the most controversial and potentially damaging activities in Yukon.

In summary the procedures that are used in considering and evaluating various water use activities are flawed. There are no sound procedures for considering proposals, no standards for decision-making, there is no provision for administrative flexibility to compare the benefits of one type of resource use (e.g. placer mining) with other resource uses, nor is there a provision to aid in determining which pattern of use would best serve the public interest.

The land use permitting and approval system

Structure and function

The Territorial Lands Act (1970) and the Territorial Land Use Regulations (TLUR) (1972) constitute a system for controlling northern land use operations. The term land use operation is used to cover the normal activities of resource exploration or extraction operations which could result in damage to land. Generally, short term activities (road-building, airstrip construction, fuel storage, quarrying, camp-sites, powerlines, hydro-projects, pipelines and forestry operations) qualify as operations requiring authorizations (DIAND, 1985). The activities of a Northern resident (fishing, hunting, trapping) are expressly excluded from the definition of a land use operation (Beauchamp, 1976).

The TLUR set up a system whereby (1) initiators of land use operations apply for a permit, (2) a permit approval system is established, with fees, conditions and provisions for modifications, and (3) inspection and enforcement measures are specified.

Upon receipt of an application, the Land Use Engineer (Head, Land Use Unit) decides whether to reject the application as incomplete, or accept it and determine the class of permit required. Class B permits are for small operations and are normally issued directly by the Engineer within ten days of receipt of the application. Class A permits are required for all significantly large operations and any operations in areas of special sensitivity. They may be issued within 10 days of application, however if the Land Use Section (DIAND) requires consultation with other departments, the applicant may have to wait for up to 42 days, or even 12 months, before a permit is issued. Class A

applications are forwarded to the Land Use Advisory Committee (LUAC), the Ottawa Land Use Office, and the DIAND district office (District Land Use Inspectors) for review, comment and recommendations.

The LUAC committee meets once a month to review major class A applications. All class A applications are circulated to all members of LUAC. A full review is initiated only if at least two members voice concern over some aspect of the application (Savoie, 1985).

It is the Land Use Engineer's responsibility to decide on the terms and specific operating conditions of a permit; reject the application and return it to the applicant stating the reasons for turning it down; or to order a detailed land inspection, postponing a final decision for up to one year.

The Territorial Land Use Regulations (TLUR) also specify inspection and enforcement measures as follow-up to the permitting system. Interim inspections during the operation and a final inspection upon completion of the program are meant to prevent environmental problems and monitor the permittee's compliance with the terms and conditions of the permit (DIAND, 1981).

Critique of the approval system

There are a number of significant problems with the Territorial Lands Act and the Regulations that limit the effectiveness of the land use review and approval system, and illustrate why a regional environmental assessment process is required.

(1) There are two striking constraints on the Act and the Regulations, (1) a provision within the TLA maintains that nothing in the Act shall limit the operation of the Yukon Quartz Mining Act or the Yukon Placer Mining Act, and (2) anything done in the course of prospecting, staking or locating a mineral claim is exempt from the TLUR.

The Yukon Placer Mining Act is principally concerned with defining the rights and obligations of placer miners. The YPMA makes no provision for the co-ordination of placer mining activities with other resource use, and other land uses are always subordinate to placer mining at placer mining sites (Fox, 1984). The Yukon Quartz Mining Act (YQMA) pertains to the administration of the subsurface for hardrock mineral deposits and provides virtually no environmental protection (Dacks, 1981).

The major problem associated with Yukon mining legislation is the absence of any provisions relating to environmental protection. No provisions exist for reclamation, revegetation, or restoration. Currently, approximately 14,450 sq. km of the Yukon is under mineral claim (O'Reilly, 1984) and therefore not bound by the TLUR. In some instances (e.g. in providing access trails) claim staking has been used to circumvent the Regulations (DIAND, 1984a).

(2) A major weakness in the system is the apparent conflict of interest between the development and conservation responsibility of DIAND. The administration at DIAND is meant to "facilitate resource development" and "provide a service to industry". Yet the Territorial Land Act is meant to protect the ecological balance or physical characteristics of any land management area in Yukon. Although it may be argued that these two responsibilities can only be effectively administered through one department, DIAND does not necessarily put conservation and development on an equal basis. Nor can the tradeoffs that are made necessarily be better made by public servants than in a public or political area.

(3) The Land Use Advisory Committee (LUAC) exists without a formal mandate or terms of reference, it is not structured in legislation and functions at the discretion of DIAND. The Land Use Advisory Committee (LUAC) works as a mechanism by which members of various departments and agencies may review major land use applications and voice concern and suggest recommendations prior to the commencement of any operation/activity. However the discretionary and advisory nature of the committee limits the validity of the approval system because there is no guarantee that the committee's input will be sought and incorporated into the final decision. As well, approximately 60% of the committee is comprised of employees of DIAND, which may introduce bias since DIAND has a substantial interest in non-renewable resource development and has to act as both a facilitator and regulator of northern development.

(4) The discretionary powers that are afforded to the Land Use Engineer are very broad. Since the LUAC is advisory in nature only, and all decisions ultimately rest with the Engineer, the TLUR are, essentially the Land Use Engineer. Although it has not yet happened, the potential for abuse in this situation is quite clear. The Land Use Engineer can circumvent legitimate LUAC recommentions. Furthermore, one person cannot hope to accommodate a wide range of values and interests with respect to the land. Thus, decentralization of the Land Use Engineer's decision-making power is necessary to ensure that "all public interests" are being served.

(5) There is no provision for public participation in any aspect of the administration of the Act or Regulations. Class A applications are circulated to the Council for Yukon Indians and the Yukon Conservation Society for notification purposes only (Savoie, 1985). Community consultation is expected to be dealt with by the Government of Yukon's Department of Community Affairs (a LUAC member) — although there is no mechanism to ensure that this happens. Renewable resource users (especially hunters, fishermen, trappers and wilderness recreationists) are not provided with any notification of intended land use operations in the area — nor is there any mechanism to provide compensation to renewable resource users.

In summary, the land use permitting and approval system is limited in a number of respects. It is oriented towards the control and regulation of short-term development projects and generally allows all activities, with some sort of mitigation to decrease environmental damage. It does not recognize land uses/activities that fall outside of its classification scheme, thus it can potentially create more conflict than it addresses. No mechanism exists by which affected existing land users may be notified of proposed operations or voice

their concerns. There is no guarantee to the general public that land use activities are being assessed, evaluated, controlled and regulated with the best interest of the public in mind.

Summary and conclusions

Although Yukon has a few limited environmental assessment and review mechanisms in place they are incomplete — all lack in some important aspect. The significant flaws in the federal process (EARP) are that the full review process applies to only a very few proposed activities in Yukon and for those activities the outcomes and recommendations of the assessment process are not legally enforceable. The water use and approval process lacks a full and explicit consideration of the social, cultural and ecological effects and is potentially biased toward pressing and urgent new uses of water and against long standing traditional uses. The land use and approval system is the worst offender — it does not seek full and frank discussion of all of the effects associated with an activity, it does not seek public review and input over any activity, it does not seek to apply to the most environmentally degrading land uses in Yukon (mining) and the ultimate decision rests with one civil servant — who is not legally bound to any advice or recommendations by affected parties.

Common flaws in all of the mechanisms reviewed are the failure to address cumulative impacts (particularly the cumulative impacts associated with numerous minor activities) and the failure to address cross-media impacts (for example, how land use activities affect water activities).

These flaws illustrate that the existing processes are unable to deal effectively with issues relating to environmental protection and natural resource development. The existing processes are inadequate because the objectives of much of the legislation focuses on growth and development. The priority is often national development goals over local or regional ones. Because of this emphasis — environmental concerns (which are grounded in the perceptions and values of society) are not likely to be given equal consideration.

An environmental assessment mechanism for Yukon would be able to address these problems. An EA mechanism is a means by which the economic benefits and the environmental costs of an activity can be measured and balanced; the rights and needs of the region can be recognized along with national priorities; and the locally affected public can assist in determining trade-offs to ensure the greatest net public benefit. Other advantages of a formal environmental assessment mechanism for Yukon are that it can remove a certain amount of discretion from decision-making and thereby reduce uncertainty; and it can ensure consistency in evaluation and reduce overlap, clarifying the rules and procedures for proponents of activities. As well, an environmental assessment mechanism would assist Yukon in its attempts to achieve compatibility between environmental protection and economic development.

References

Beanlands, G. and P. Duinker 1983 An Ecological Framework for Environmental Impact Assessment in Canada, Halifax: Dalhousie University and FEARO.

Beauchamp, K. 1976 Land Management in the Canadian North, Ottawa: CARC.

Boothroyd, P. and W. Rees 1984 "Impact Assessment from Pseudo-Science to Planning Process: an Educational Response" Discussion Paper No. 3, School of Community and Regional Planning, Vancouver: University of British Columbia.

Dacks, G. 1981 A Choice of Futures, Politics in the Canadian North, Toronto: Methuen.

DIAND 1981 Guidelines to the Territorial Land Use Regulations, Ottawa: Canada.

_____ 1984 Land Use Guidelines Access Routes and Trails. Prepared by Hardy Associates (1978) Ltd. Ottawa: DIAND.

_____ 1985 The Northern Mineral Sector: A Framework for Discussion March, 1985.

Emond, P. 1978 Environmental Assessment Law in Canada, Toronto: Emond-Montgomery Ltd.

_____ 1983 "Fairness, Efficiency and FEARO: An Analysis of EARP" pp. 49–74, in (eds) Case, E.S., Finkle, P.Z. and A. Lucas, 1983 Fairness in Environmental and Social Impact Assessment. The Canadian Institute of Resources Law, University of Calgary.

FEARO 1983 "Improvements to the Environmental Assessment and Review Process (EARP)" Discussion Paper for Interdepartment Review, February 28, 1983.

_____ 1986 Initial Assessment Guide. Duffy, P. (ed.) Federal Environmental Assessment and Review Office.

Fox, I. 1984 "An Assessment of Legal and Administrative Arrangements Related to Placer Mining in the Yukon River Basin" University of British Columbia. Burnaby: Westwater Research Centre.

Fox, I., Eyre, P. and W. Mair [no date] Yukon Water Resources Management Policy and Institutional Issues. Westwater Research Centre, Vancouver: University of British Columbia.

Hunt, C.D. and A.R. Lucas 1981 Environmental Regulation: Its Impact on Major Oil and Gas Projects, Oil Sands and Arctic. Calgary: Institute of Resources Law.

MacLeod, W. 1977 Water Management in the Canadian North. The Administration of Inland Waters North of 60, CARC: Ottawa.

O'Reilly, K. 1984 "An Evaluation of the Territorial Land Use Regulations as a Land Management Tool in the Yukon" unpublished Master of Arts Thesis, University of Waterloo.

Order-in-Council 1984 "Guidelines respecting the Implementation of Federal Policy on Environmental Assessment and Review" 1984-482.

Pearse, P.H., Bertrand, F. and J.W. MacLaren 1985 Current of Change, Final Report Inquiry on Federal Water Policy, Ottawa.

Rees, W. 1981 "Environmental Assessment and the Planning Process in Canada" S.D. Clark (ed.) Environmental Assessment in Australia and Canada, Vancouver, Westwater Research Centre, UBC.

Savoie, P. 1985 Personnel Communication. Head, Land Use Unit, Land Resources Section, Renewable Resources Division, DIAND, Whitehorse, Yukon.

Appendix 1: Statutes

Environment protection statues

Fisheries Act is concerned with both inland and ocean fisheries. Its major focus is protection of fish and their habitat from physical interference and pollution. In the Yukon Territory, fish protection is undertaken by the Department of Fisheries and Oceans whereas habitat protection is managed by the Environment Protection Service of the Department of the Environment. The Act is prohibitory rather than managerial in nature.

Canada Water Act provides for the development and implementation of water management and water quality management plans for river basins by appropriate intergovernmental agencies. These plans are often based on interjurisdictional agreements, as these basins are rarely confined to a single province or territory. The Yukon River Basin Study was undertaken under this Act.

Canada Shipping Act has extensive provisions dealing with pollution which might be applied to shipping on the Yukon River. The bulk of the Act is concerned with regulating and controlling shipping in Canadian waters south of 60 latitude north.

National Parks Act. Under this Act, Parks Canada is created as an agency of the Department of the Environment. It is responsible for administering national parks and controlling development within them in accordance with the statute. To that end it is given extensive powers within parks, including control of natural resources.

Canada Wildlife Act provides for wildlife management, particularly of endangered and migratory species. The Act is administered by the Canadian Wildlife Service of Environment Canada. In the Yukon, the primary responsibility for wildlife management resides with the territorial government pursuant to the Yukon Wildlife Act.

Migratory Birds Convention Act provides for the management and conservation of migratory birds, as part of the Migratory Birds Convention between Canada and the United States. It is administered by the Canadian Wildlife Service.

Northern Inland Waters Act and *Regulations* provide for the conservation, development and use of the water resources of the Yukon and N.W.T., and for the establishment of Water Boards in each area to license all such water usage and waste disposal. The administration of the Act is provided by the Water Resources section of DIAND.

Territorial Lands Act controls the disposition and use of all territorial lands, save for mining. It is administered by the Renewable Resources Branch of DIAND.

Territorial Land Use Regulations establish land management zones and a permit approval system to regulate and control land use in the Territories.

Arctic Waters Pollution Prevention Act and *Regulations* govern development and shipping activity in Arctic waters adjacent to the mainland and islands of the Canadian Arctic, to ensure the continuing welfare of the residents of the area, and to protect the ecological balance in water, ice and land areas. It includes a detailed approval system to prevent pollution of Arctic waters by means of controls on discharge of waste and controls on the design and operation of ships.

Canada Oil and Gas Drilling Regulations provide for the control of drilling operations, the prevention of pollution and the safety of personnel directly involved with wellsite operations. The regulations specify minimum technical requirements for a variety of operations, many of which have environmental protection significance in that compliance is likely to reduce the risk of an environmentally damaging failure or accident.

Resource development and control statutes

Dominion Water Power Act defines dominion water powers and regulates structures which utilize them. It is particularly applicable to actual and potential hydro sites in the territories, although it has been largely superseded by the Northern Island Waters Act. The Act is administered by the Renewable Resources section of DIAND.

Navigable Waters Protection Act. The major purpose of this Act is to prevent obstruction of navigable rivers such as the Yukon. Obstructions primarily include dams, docks, and other industrial uses, but fishing apparatus and the like are also controlled. The statute essentially prohibits obstructions and diversions of navigable waters unless a permit is first obtained.

Yukon Placer Mining Act controls all aspects of placer mining except (since the Northern Inland Waters Act was passed in 1970) the allocation and use of water for that activity. It is administered by the Non-Renewable Resources section of DIAND.

Yukon Quartz Mining Act contains provisions similar to the *Canadian Mining Regulations* as they concern lode (bedrock) minerals in Yukon. (The *Canadian Mining Regulations* specify licence requirements, marking and recording of claims, work performance, lease rentals and production royalties, and other procedures.)

Territorial Dredging Regulations govern the disposition of rights to dredge for minerals in the underwater beds of rivers in Yukon and N.W.T.

Territorial Quarrying Regulations govern the use of Crown-owned limestone, granite, slate, marble, gypsum, loam, marl, gravel, sand, clay, volcanic ash or stone in territorial lands. The regulations specify lease requirements, applications, fees and royalties, and other procedures.

Territorial Coal Regulations govern the disposition of rights to coal in Yukon and N.W.T.

Territorial Timber Regulations control the harvesting of the timber resources of Yukon and N.W.T. by requiring operators to obtain permits for cutting trees.

Northern Canada Power Commission Act creates the Northern Canada Power Commission. It is empowered to seek out and develop northern power sources, including hydroelectric, so as to satisfy the needs of northern communities and industry. It does not have a monopoly. Proposed developments are subject to approval by the Minister of DIAND.

Canada Oil and Gas Act provides for the disposal of rights to search for and take oil and gas from Canada lands; for the control and regulation of exploration activities; and for the payment to the Crown of fees, rentals royalties, etc.

Canada Oil and Gas Production and Conservation Act provides broad authority for the control of all activities associated with drilling, production, conservation and transportation of oil and gas in Canada lands so as to prevent waste and avoid pollution. It is administered by the Non-Renewable Resources Branch of DIAND.

The information was derived from *Northern Natural Resource Developments: Requirements, Procedures, and Legislation*, Northern Affairs Program, Indian Affairs and Northern Development, 1981 and Thompson, A.R. and A. Ourom, "Legal and Administrative Arrangements for Yukon River Basin Management", March 1984, Westwater Research Centre, University of British Columbia, Vancouver.

WETLANDS AS WASTE REPOSITORIES?: SOLUTE TRANSPORT IN PEAT

Jonathan S. Price and Ming-ko Woo

Department of Geography, McMaster University, Hamilton, Ontario L8S 4K1

Level: J.S. Price, Ph.D.

Abstract

The huge wetland reserves of the temperate and subarctic zones are increasingly viewed as potential low level toxic waste repositories; thus their ability to assimilate these wastes is considered. Processes which govern the transport of a non-reactive solute through peat are examined. A series of chloride solute breakthrough experiments was carried out to determine the nature and magnitude of chloride transport in peat, using undisturbed peat columns collected in the frozen state from a southern James Bay wetland. A chloride solution was introduced into a permeameter, and the chloride content of the outflow was determined and plotted against time to produce breakthrough curves. These curves indicated that retardation of chloride occurred. Higher velocity trials produced less dispersion than those at low velocity, which is opposite to what occurs in mineral soils. Retardation of chloride was considered to be due to the temporary entrapment of the solute in closed peat pores. In higher velocity trials less time was available for inward diffusion and for the loss of solute to the closed pores, hence less dispersion was evident. The results indicate that solutes in general move through peat more slowly than through mineral soils with the same true porosity, and that dispersion caused by uptake of the solute will reduce the solute concentration downstream of the source. Although this property of peat may make some wetlands amenable for use as low level toxic waste disposal sites, the influence of their complex and variable hydrological regime cannot be overlooked.

Key words: Solute transport, peat, wetlands, pollution, chloride.

Résumé

On considère de plus en plus les énormes superficies de terres marécageuses des régions subarctiques comme des décharges éventuelles pour les déchets de faible toxicité, et on étudie donc leur capacité à fixer ces derniers. Les auteurs décrivent les processus qui gouvernent le déplacement des corps dissous non réactifs au travers de la tourbe. Ils ont effectué une série d'expériences sur la nature et l'ampleur de la pénétration de solutions de chlorures dans des carottes de tourbe non perturbée, prélevées à l'état congelé dans une tourbière du Sud de la baie de James. Ils versaient la solution de chlorure dans un perméamètre et mesuraient la teneur en chlorure de l'effluent, ce qui leur permettait de tracer les courbes de percolation en fonction du temps. Ces courbes mettent en évidence une rétention des chlorures. Les essais à vitesse élevée ont produit une dispersion moindre que ceux menés à faible vitesse, contrairement à ce qui se produit dans les sols minéraux bruts. Les auteurs considèrent que la rétention des chlorures est causée par la capture temporaire de ces corps dissous dans les pores sans issue de la tourbe. Au cours des essais menés à vitesse élevée, la diffusion interne de la solution était plus restreinte, et la rétention des chlorures dans les pores sans issue était plus faible. Ces résultats indiquent qu'en général les corps dissous se déplacent au travers de la tourbe plus lentement que dans les sols minéraux bruts de même porosité effective, et que la dispersion causée par l'absorption des corps dissous réduit la concentration des effluents en aval de la source.

Mots-clés: Mouvement des corps dissous, tourbe, terres marécageuses, pollution, chlorures.

Introduction

Wetlands have recently received attention as potential repositories for low level toxic waste (Nichols 1980, Toth 1980). Thun *et al.* (1983) report that peat can remove oil, fats, proteins, detergents, dyes, radionuclides, and heavy metals from water. Unfortunately, the nature of subsurface water movement, and thus contaminant migration in wetlands is poorly understood at both the micro- and macro-scale levels. For example, the capacity of wetlands to attenuate contaminants may vary seasonally as a function of water table level, as surface flow and near surface flow through peat is many orders of magnitude greater than in lower layers where decomposed peat has lower hydraulic conductivity (Boelter 1964). At the micro-scale level, difficulty in parameterizing the hydraulic properties of organic material (Boelter 1975) leads to uncertainty in the mathematical representation of the transport processes.

A process oriented approach to solute transport in peatlands has only recently been considered. Loxham (1980) has provided perhaps the first general discussion of the concepts involved. Loxham and Burghardt (1983) modelled solute transport in peat using the analytical solution of Tang *et al.* (1981) for solute transport in linear fractures. Mannerkoski (1980) observed lithium diffusion in peat as a basis to estimate the rate of upward migration of potassium. The nature of the processes controlling solute transport in peat are not well known, however. The objective of this study is to determine the ability of peat to retard the transport of a non-reactive conservative solute in groundwater, and to identify the processes which control this.

Solute transport through peat

Solute transport through porous granular geologic media has received considerable attention (Freeze and Cherry, 1979; Gillham *et al.*, 1982; and Cherry *et al.*, 1984). The transport of a non-reactive constituent in saturated homogeneous porous media is described by the advection-dispersion equation. In the one dimensional form this is:

$$\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2} - \bar{v} \frac{\partial C}{\partial x} \qquad (1)$$

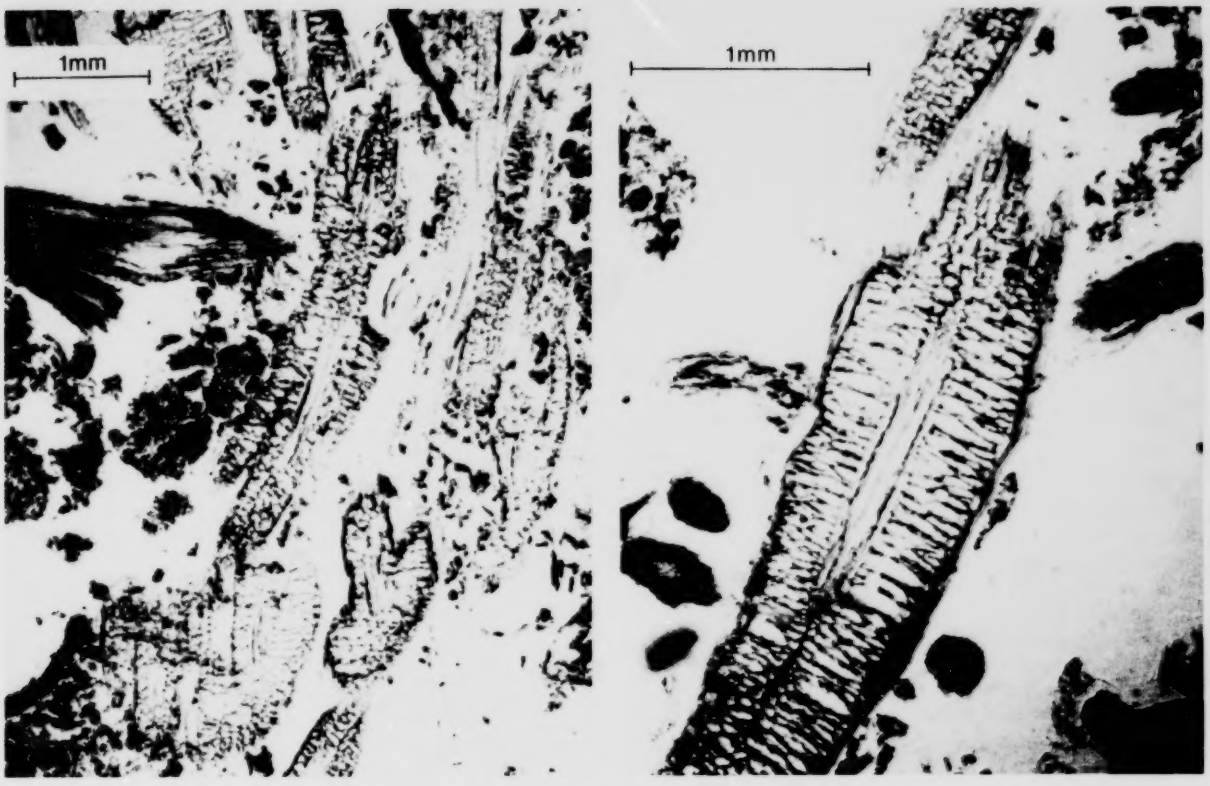


Plate 1. Thin section of peat used in experiments:
(a) typical distribution of plant remains, and
(b) close-up showing closed cellular structure.

where C is the solute concentration, t is time, x is distance along the flow path, D is the co-efficient of dispersion, and $\bar{v}$ is the linear velocity:

$$\bar{v} = \frac{v}{n_a} \qquad (2)$$

where v is the Darcy velocity and n_a is the effective porosity. In unfractured granular material, solute transport occurs only in the pore spaces between grains, and interaction of solute (eg. sorption) with soil particles occurs at the grain surface. As peat is formed of cellular plant remains (Plate 1), solid surface boundaries are not present as in geologic material, and this influences both hydraulic and solute transport characteristics. In peat, therefore, it is important to distinguish between those active pores capable of transmitting water (and solute) by advection, and those which are not. Peat pores may be open and connected, dead-end or isolated, or composed of closed or partially closed cell remains. Only the open connected pores transmit advective flow, and thus comprise the effective, or active porosity of peat (n_a). The inactive pores and cellular structure isolate a portion of the water within the sample in which no advective solute transfer can occur. This active zone may act as a sink to solutes which pass through the adjacent active pores. As the solute front advances, solution migrating through the active pores is initially at a higher concentration than in the closed (inactive) pores. Consequently, Fickian diffusion occurs in response to the concentration gradient between active and inactive pores and cells, removing solutes from the advected solution. The amount of solute lost is a function of the concentration gradient between active and inactive pores, the relative proportion of these pore types, and the diffusion co-efficient for the solute. This loss term (Q) can be added to eq. (1) so that:

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - \bar{v}\frac{\partial C}{\partial x} - Q \qquad (3)$$

Experimental methods

Breakthrough experiments are performed by introducing a tracer (e.g. chloride) continuously at concentration C_o into a steady state flow with initial concentration $C = 0$ at time $t = 0$. The plot of outflow concentration versus time is the breakthrough curve. The outflow concentration is expressed as C/C_o, which is a dimensionless concentration. The time ordinate is also expressed in a dimensionless form as τ, which is the volume of outflow divided by total empty column volume.

A series of solute breakthrough experiments was carried out to determine the magnitude of chloride retardation in peat, and to try to gain insight into the process. Breakthrough

experiments were carried out on a peat core (80 mm dia. × 110 mm) taken from a southern James Bay coastal wetland in April 1985. The peat contains a combination of poorly decomposed (Von Post #2) mosses and sedges, with no major wood inclusions. The sample selected was from 0.10–0.21 m in the peat profile, and was of relatively uniform decomposition. The properties of the sample used are listed in Table 1. The active porosity was measured from thin sections and was 60±5%.

TABLE 1
Hydraulic characteristics of peat core

Sample Depth (m)	0.1 – 0.21
Dry Bulk Denisty (kg m^3)	87.0
Specific Yield (%)	14.0
(n_t) Total Porosity (%)	92.5
(n_a) Active Porosity (%)	60±5

The frozen core was allowed to stand in cold air for several days to allow the outer few millimeters of the core to dry through sublimation. The core (still frozen) was rolled in liquid paraffin wax that bonded securely to the dried outer edges of the core. The core was then inserted into an 8 cm dia ABS pipe, and molten wax trickled between the core and the pipe, making a tight hydraulic seal. A permeameter of similar design to that described by Freeze and Cherry (1979) was used to introduce a 12,500 mg/l chloride solution (step change input). Several tests were performed at different velocities.

To determine if chloride sorption onto peat could be detected, batch tests (Freeze and Cherry, 1979) were performed on wet and dry peat samples. The chloride solutions were mixed with peat samples of known weight to determine whether any chloride was removed from the solution in the reaction vessel (i.e. by sorption onto the peat). Peat samples of 5 to 10 g (dry weight) were saturated with 100 ml of 10; 100; 1000; 10,000; and 20,000 mg/l chloride solution, stirred for 10 min. on a magnetic stirrer, and allowed to equilibrate for 24 h. The supernatant was decanted, filtered, and solution activity was adjusted with 5 M $NaNO_3$ (ionic strength adjuster) before the chloride analysis was performed. An Orion™ combination chloride electrode was used to analyze all samples (batch and breakthrough).

Results and discussion

In the batch experiments, Cl^- concentration after 24 h in the reaction vessel was the same as the starting concentrations for all solution concentrations used. This indicated that there was no chloride adsorption onto the peat samples.

Results of "high" and "low" velocity breakthrough experiments are shown in Figure 1. The long tails are evidence of some retardation mechanism at work. The sharply rising portion of the curves are peculiar in that the "high" velocity run exhibits less dispersion than "low" velocity trial, indicated by the steepness or "spreading" of the curve. This is contrary to what would be expected in geologic material (Freeze and Cherry, 1979). Breakthrough at the C/C_o=0.9 level occurs at lower values of τ in the high velocity trial (i.e. relatively less effluent volume), but solution retardation continues long after that of the lower velocity test. These processes are due to diffusion of chloride into the closed pores. In the high velocity case, less time is available initially for diffusion into the inactive zones; hence it reaches high levels of C/C_o relatively quickly. However, some capacity to absorb chloride remains until the concentrations in active and inactive pores are in equilibrium, hence the long tail in Figure 1. At lower velocities, the loss of chloride from the solute front is better able to keep pace as there is more time for diffusion into the cells to occur. This results in greater "retardation" at lower breakthrough times.

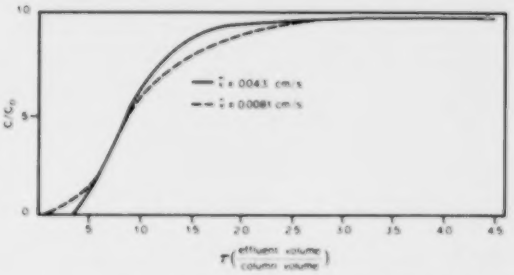


Figure 1. Chloride breakthrough curves for peat at 'high' and 'low' velocities. The steepness of the curves indicates the degree of dispersion of the solute front, and the long tail suggests retardation.

The breakthrough data were fitted with curves generated by the one-dimensional solution to the advection-dispersion equation with retardation (Ogata 1972):

$$\frac{C}{C_o} = \frac{1}{2}\left[\operatorname{erfc}\left(\frac{x-\bar{v}'t}{2\,(D't)^{-1/2}}\right) + \exp\left(\frac{\bar{v}'t}{D'}\right)\operatorname{erfc}\left(\frac{x+\bar{v}'t}{2\,(D't)^{-1/2}}\right)\right] \quad (4)$$

where erfc is the complementary error function, $\bar{v}' = \bar{v}/R$, $D' = D/R$ with R being the retardation co-efficient. There is no retardation when R=1.0. It was found that the optimum retardation co-efficients for the high and low velocity experiments were 1.5 and 1.6 respectively. The fitted curves are shown in Figures 2a and 2b, along with the unretarded case (R=1.0). Linear velocity ($\bar{v}$) was calculated using n_a=64%, which is in the upper range of the measured porosity (Table 1). This is a conservative approach in this case because it results in a lower ($\bar{v}$), thus any retardation is almost certainly due to physical processes.

The difference between the unretarded simulation and the data points of Figures 2a and 2b were calculated, and plotted against τ in Figure 3. This quantity is the mass flux of chloride lost from the advected solution by diffusion into inactive pore spaces, as represented by the right-hand term in equation 3. The time of maximum flux in both trials occurs approximately at τ=0.64, which is equivalent to n_a. This supports the concept of solute loss into inactive pores. At $\tau < n_a$, not all active pores contain the chloride solution being input. At $\tau = n_a$, all the active pores theoretically should contain chloride, and at that instant, the inactive pores have the low initial Cl^- concentration; thus the maximum concentration gradient exists, and hence the flux rate into inactive pores is greatest. At $\tau > n_a$, the increased

concentration of Cl^- within inactive pores reduces the concentration gradient, so the rate of loss from the advected solute decreases.

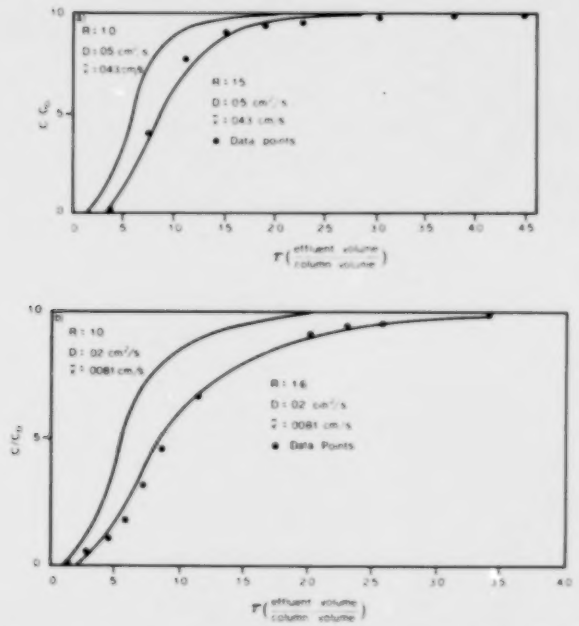


Figure 2. Chloride breakthrough data and curve fit using equation 4 without retardation (R = 1) and with retardation for (a) high velocity trial (R = 1.5), and (b) low velocity trial (R = 1.6).

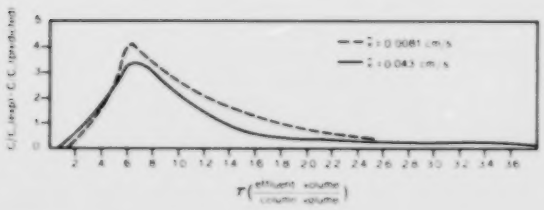


Figure 3. Difference between the unretarded solution of equation 4 (R = 1.0), and experimental data, which represents the mass flux of chloride from the solution into the inactive pores. Maximum retardation occurs near $\tau = 0.64 = n_a$.

Conclusions

The results of these experiments indicate that the physical structure of peat delays the transport of a non-reactive conservative solute due to its entrapment in closed inactive pores of the cellular remains of the peat forming vegetation. Solute was found to be removed from the advected solution by diffusion into the inactive pore spaces. The delay could not be attributed to sorption, which batch tests showed to be unimportant.

Translating a laboratory model to the field scale is problematic. No homogeneous body of peat can exist by virtue of its mode of formation, as hydraulic conductivity decreases with degree of decomposition (hence depth), and the horizontal stratification may cause an isotropy. In the longitudinal direction, discontinuity in hydraulic conductivity, hence macro-dispersivity, may be caused by changing peat structure which results from decaying patterned surface forms present in some wetlands. These problems are fundamental to "basic" groundwater hydrology in peat deposits, and may completely overwhelm any errors, inaccuracy and inadequacy of contaminant transport models.

Because of these problems, field scale modelling of contaminant plumes in wetlands seems a long way off. However, laboratory scale research can improve our understanding of the concepts involved, and can thus be used in conjunction with hydrologic data to help in decision-making concerning contaminant transport problems in wetlands.

Acknowledgments

This research was funded by a Natural Sciences and Engineering Research Council collaborative grant. Thanks are also due to Dr. C. Fox of Agriculture Canada for preparing the thin sections, and to Dr. B.T. Bunting and J. Lundburg at the McMaster Geography Department for their help in thin section analysis.

References

Boelter, D.H. 1967. Hydraulic conductivity of peats. Soil Science V. 100(4), 227-231.

_____ 1975. Methods for analyzing the hydrological characteristics of organic soils in marsh ridden areas. In: Proceedings of the Minsk Symposium, UNESCO press, Paris, 1975, 161-169.

Cherry, J.A., Gillham, R.W., and Barker, J.F. 1984. Contaminants in groundwater: Chemical processes. In: Studies in Geophysics, Groundwater Contamination, National Academy Press, Washington, D.C., 46-64.

Freeze, R.A., and Cherry, J.A. 1979. Groundwater. Prentice-Hall, Inc., New Jersey, 604p.

Gillham, R.W., and Cherry, J.A. 1982. Contaminant migration in saturated unconsolidated geologic deposits. Geological Survey of America, Special Paper 189, 31-62.

Loxham, M. 1980. Theoretical considerations of transport of pollutants in peats. Proceedings of the 6th International Peat Congress, Duluth, 600-606.

Loxham, M., and Burghardt, W. 1983. Peat as a barrier to the spread of micro-contaminants to the groundwater. Proceedings of the International Symposium on Peat Utilization, Fuschman, C.H. and Spigarelli, S.A. (eds.), Bemidji State University, Bemidji, Minnesota, 337-349.

Mannerkoski, H. 1980. Diffusion of lithium in drained peat soils. Proceedings of the 6th International Peat Congress, Duluth, 616-620.

Nichols, D.S. 1980. Nutrient removal from wastewater by wetlands. Proceedings of the 6th International Peat Congress, Duluth, 638-642.

Tang, D.H., Frind, E.O., and Sudicky, E.A. 1981. Contaminant transport in a fractured porous media: Analytical solution for a single fracture. Water Resources Research V. 17(3), 555-564.

Thun, R., Fragernas, L., and Brandt, J. 1983. Use of thermally treated peat for water purification. International Symposium on Peat Utilization. Fuschman, C.H. and Spigarelli, S.A. (eds.), Bemidji State University, Bemidji, Minnesota, 365-379.

Toth, A. 1980. Utilization of peatland for purification and emplacement of communal sewage-mud. Proceedings of the 6th International Peat Congress, Duluth, 711-712.

MUSKOX ACTIVITY PATTERNS AND PLANT COMMUNITY PREFERENCES ON CENTRAL ELLESMERE ISLAND, N.W.T.

Martin Raillard, Thomas Rahn and Josef Svoboda

Department of Biology, Erindale Campus, University of Toronto, Mississauga, Ontario L5L 1C6

Level: M. Raillard, Ph.D.

Abstract

An intensive first season study of muskox grazing was conducted in a selected portion of Sverdrup Pass in July 1986. The Pass is a deglaciated valley between two major ice fields. It connects the extensive range of muskoxen at Fosheim Peninsula with the vegetated lowlands at the east coast in the Bache Peninsula horseshoe. The valley is fairly vegetated mainly by stands of willow communities and some sedge meadows which support the migrating herds. The population of muskox was 54 animals during the July 17, 1986 census.

For the purpose of this study a representative crossection of the valley (ca. 8 km^2) was chosen in the central part of the Pass and a vegetation map of this "Intensive Study Site" (ISS) was outlined. A lookout was established on an elevated but hidden place from which the entire ISS could be observed on a 24 hour basis. The presence, position and activity (grazing, resting, moving) was observed every hour between 8.00–22.00 and every two hours between 22.00–8.00 and recorded on the map. From the collected data the following information was extracted: the animal migration patterns, preference for plant communities, mean rate of travel, mean occupation time within the ISS and preferred communities. From the beginning till mid-July the animals grazed mainly in the willow stands, later meadows were more utilised. Many stands were visited by the migrating herds repeatedly and grazed intensively. Our observations suggest that the vegetation of the Sverdrup Pass is under severe grazing pressure. However a dynamic equilibrium has been established between muskox population and the vegetation complexes and is maintained by the positive plant-herbivore interactions.

Key words: Ellesmere Island, Sverdrup Pass, muskox grazing.

Résumé

En juillet 1986, les auteurs ont mené une étude intensive sur le pâturage des boeufs musqués dans une aire choisie du passage Sverdrup. Ce passage est constitué par une vallée libérée des glaces entre deux glaciers très étendus, et il relie les vastes pacages à boeufs musqués de la péninsule de Fosheim avec les terres-basses couvertes de végétation du littoral oriental de la péninsule en fer à cheval de Bache. Cette vallée est moyennement couverte par la végétation, surtout par des peuplements de saules et quelques prairies à carex qui nourrissent les troupeaux de passage. La population de boeufs musqués était de 54 animaux lors du relevé effectué par les auteurs le 17 juillet 1986.

Pour les fins de leur étude, les auteurs délimitèrent une aire transversale représentative de la vallée, et d'environ 8 km^2, dans la région centrale du passage, et établirent une carte de sa végétation. Ils installèrent un mirador dans un lieu élevé mais dissimulé, d'où ils pouvaient observer toute l'aire d'étude 24 heures par jour. Ils notèrent la présence, la situation et l'activité des animaux (pâturage, repos, déplacements) toutes les heures de 8 h à 22 h et toutes les deux heures de 22 h à 8 h, et reportèrent les données sur la carte. Ainsi ont-t-ils recueilli les informations suivantes: déroulement de la migration des boeufs musqués; leurs associations végétales préférées; la rapidité moyenne du déplacement et la durée moyenne de présence dans l'aire d'étude. Du début à la mi-juillet, les animaux pâturent surtout dans les peuplements de saules mais, plus tard, ils fréquentent les prairies de carex. De nombreux peuplements ont été visités successivement par les troupeaux en migration, et broutés intensément. Les auteurs estiment, d'après ces observations, que la végétation du passage Sverdrup est soumise à un pâturage très intense. Cependant, un équilibre dynamique s'est établi entre la population de boeufs musqués et les associations végétales, et il est maintenu par les interactions positives entre plantes et herbivores.

Mots-clés: Île d'Ellesmere, passage de Sverdrup, pâturage des boeufs musqués.

Introduction

The daily activity pattern and habitat use of muskoxen have been the focus of studies at various sites in the Canadian High Arctic. Some preliminary results of a more comprehensive study designed to answer questions about muskox tundra interactions and provide information on muskox in Sverdrup Pass, Central Ellesmere Island, are presented here. After one season of observation, data on plant community preference and temporal pattern of grazing *vs.* resting are available. Other objectives of the long term study are:

1) To evaluate the relative importance of plant communities for the muskox.
2) To determine the capacity of the vegetation of Sverdrup Pass to sustain further growth of the local muskox population.
3) To determine the impact of grazing on various plant communities in the Pass.

Previous studies of plant community preference were conducted on Axel Heiberg and Melville Island by Parker and Ross (1976), on Banks Island by Wilkinson *et al.* (1976), on Jameson Land, Greenland, by Thing (1984), on Melville Island by Thomas and Edmonds (1984), and on the Taimyr Peninsula (USSR) by Rapota (1984). Most of these studies suggest that grazing muskox strongly prefer the wet meadow community type; however, some references show that willow-dominated communities are equally important for grazing.

Findings on daily activity pattern also vary: Gray (1973) and Jingfors (1980), studying populations on Bathurst Island and Alaska respectively, found no daily periodicity while Pederson (1958) and Sittler and Kempf (1984) observed longer resting periods at midday in Greenlandic muskox.

Study area

Sverdrup Pass is a ca. 80 km long deglaciated valley, lying at 79°N between two major icefields. It is the sole link and migration corridor between the lowlands of the Bache Peninsula horseshoe in the east and the relatively lush Fosheim Peninsula plain in the west. Repeated censuses of the muskox population in the Pass have found the following population sizes: June 1982 – 47 muskox, July 1983 – 65 muskox, July 1984 – 37 muskox (Henry *et al.* 1986) and July 1986 – 54 muskox.

The valley varies between two and five kilometers in width and is extensively covered by fluvio glacial outwash fans and other subglacial and erosion products. Areas of more substantial vegetation (cover > 10%) are generally small, scattered and limited to wetter areas on slopes, near streams and below snowbanks seepages.

Methods

The vegetation was mapped on the basis of aerial photographs and a ground survey of a ca. 3 × 2 km section of the Pass, near the divide which became a permanent study site. A hidden lookout, established approximately 50 m above the valley floor on a lateral moraine, allowed the unobstructed observation of the muskox through binoculars and a 20× telescope. The activity and location of each muskox in the study area were recorded, with few small breaks, almost continuously from 17 to 31 July; hourly from 8.00 to 22.00 h and every two hours from 22.00 to 8.00 h. The activities observed and recorded on a vegetation map were grazing, resting and other. For each observation, air temperature, wind speed and direction and weather conditions were also recorded. A total of 176 observations were made.

To obtain a comparison of the relative time spent at each activity, the percentage of muskox grazing was calculated for each observation. The percentiles showed a skewed distribution. Consequently the most suitable statistic, for determining whether the differences between the mean percentages of muskox grazing at different times of the day were significant, was the nonparametric Kruskal-Wallis analysis of variances test. Because only two categories of activity (grazing or resting) were used, the percentage of animals resting is the converse, and the differences between times of the day are not significant. To evaluate community preference, the number of muskox at each observation were summed for each community. The normal distribution of these sums permitted a simple ANOVA to determine whether significant differences exist in the utilization of communities. To determine whether the differences in the means between the scattered willow community, the wet meadows and dry slope tundra were significant, a series of t-tests was carried out on paired combinations of the data from these communities. These communities were singled out for testing because they occupied ca. 80% of the map area and were also the most frequently visited.

To determine the preference of muskox for community types, selectivity values of both resting and grazing were calculated for the three community types. The selectivity value (from Raillard, 1985 and Leoni, 1985) correlates the percentage of all muskox observed in a community type with the community's spatial extent. The formula chosen is

$$Si = \frac{m_i - r_i}{m_i + r_i}$$

$$\text{where } m_i = \frac{\Sigma \text{ muskox in community i}}{\Sigma \text{ all muskox (grazing or resting) in the study site}}$$

$$\text{and} \quad r_i = \frac{\text{Area occupied by community i}}{\text{Total Area of study site}}$$

The value of S, the selectivity for grazing or resting in community i, is a range between −1 and +1; where negative values indicate aversion and positive values indicate preference.

Results and discussion

The vegetation in the study area where muskox activity was observed was more abundant than average for the valley. A complex of eleven plant communities was identified. Only three were found to be really significant for the muskox:

SCATTERED WILLOW: This community type covered 45% of the study site and occurred on a dry, paved, substrate, which was often partially or completely covered by a layer of fine windblown silt. Creeping willow plants formed mats whose density varied considerably from an average of 50% cover to areas that were almost barren.

WET SEDGE MEADOW: A continuous mat of peat and moss which supports a high density of graminoids and a few herbs. It covered about 18% of the study area. This community type was usually found in flat areas at the foot of the valley side where runoff from snowbanks in the hills assured a steady water supply over the growing season. The dominant species was *Carex aquatilis*. Other sedges and grasses were also present, although of these only *Alopecurus alpinus* reached significant density.

DRY SLOPE TUNDRA: Occurred in 17% of the study area. This community type is characterised by a diversity of co-dominants: *Carex rupestris*, *Carex nardina*, *Dryas integrifolia*, *Saxifraga oppositifolia* and *Cassiope tetragona*. It occurs on well drained sandy substrates on the valley slopes and upland plateaus, which had sufficient moisture during and after the snowmelt but were dry later in the season.

The muskox spent more time grazing than resting and ruminating. Grazing accounted for 59% of all activity, resting for 39% and other types of activity for 2%. These results are in agreement with the findings of Gray (1973), Parker and Ross (1976) and Sittler and Kempf (1984). Thus the contrasting prevalence of muskox resting reported by Wilkinson *et al.* (1976) and Jingfors (1980) could not be supported by our results.

The differences between activity rates through the day were not significant ($P > 0.05$). A similar absence of a clear diel periodicity was found by Gray (1973) and Jingfors (1980). These results contrast with the studies of Pedersen (1958) and Sittler and Kempf (1984), which show longer resting periods around noon. Factors which affect activity patterns of animals are generally: differences beween day and night,

predation, weather variation and food requirements. In Sverdrup Pass, all factors, except food requirements are unimportant.

The differences between day and night are not conspicuous in summer because of the latitude of the site (79°N).

Predation is not a significant factor as no fresh evidence of wolves or bears was found. More conclusive was the presence of a disabled limping bull. This animal was observed seven years ago (Heather Gill, personal communication) and has not fallen victim to predation.

Temperature variation, which Sittler and Kempf (1984) suggest influenced activity patterns of muskox in Greenland, was not an important factor in Sverdrup Pass during 1986. The average temperature was only 2.2°C higher at noon than at midnight over the period of observation. This is significantly less than the 10°C variation reported by Sittler and Kempf (1984).

Jingfors (1982) reported 3–4 complete cycles of grazing/resting during the winter and 6–7 cycles in midsummer. The shorter summer cycle of grazing/resting corresponds to a greater availability and quality of food. Thus larger quantities can be consumed in less time and the higher quality allows faster rumination and digestion. Similar control of the activity pattern by food quality has been reported by Thomson (1973) and Turner (1984). Muskox seem to be a special case in this regard because their activity pattern is mainly controlled by food requirements but not synchronized with the 24 hour earth cycle.

The time spent grazing in the wet sedge meadow and the scattered willow community was almost the same (no significant difference: $P > 0.05$). The number of animals resting in the scattered willow community was significantly greater than for all other communities ($P < 0.05$). The time spent grazing and resting in the dry slope tundra was significantly less than in both other communities ($P < 0.05$).

Selectivity includes the time spent in the communities and in addition the surface area of this community. The selectivity values (Table 1) are more helpful for showing the impact of the muskox on plant communities. The values show a clear grazing preference for wet meadows (+0.357) over scattered willow (−0.263) and dry slope tundra (−0.443). Also suggested is a preference for resting in scattered willows (+0.137) over wet meadows (−0.098) and dry slope tundra (−0.649).

The preference for summer grazing in wet meadows has often been observed (Wilkinson 1976, Parker and Ross 1976, Hubert 1977, Parker 1978, Thing 1984, Thomas and Edmonds 1984, and Rapota 1984). In Sverdrup Pass, this grazing strategy is also found.

TABLE 1
Preferences of muskox for three plant communities. Negative values indicate aversion and positive values indicate preference. Maximal values would be −1 and +1

Plant community	Selectivity for grazing	Selectivity for resting
Scattered willow	−0.263	0.137
Wet meadow	0.357	−0.098
Dry slope meadow	−0.443	−0.649

The avoidance of the dry slope tundra agrees with Parker (1978) who found only small amounts of *Dryas integrifolia*, *Carex nardina* and *Carex rupestris* in faecal and rumen samples of muskox. These species are the dominants in this community type.

Little mention is made in the literature of preferred resting sites. One such location was identified on an oblique ridge in the northwest corner of the study area. The site was almost bare with reddish gravel and scattered erratics. High density of summer and winter faeces and loose muskox hair was evidence of the site's frequent use for resting. Through the identification of preferred resting and grazing locations, it will become possible to see the landscape through the muskox's eyes.

Acknowledgments

We gratefully acknowledge the assistance of Greg Henry, Sarah Tautuajuk and Kermit Ritland in collecting and making sense of the observations for this paper. The study would not have been possible without NSERC and NSTP (DINA) grants and the radio and logistical support of Polar Continental Shelf Project.

References

Gray, D.R. 1973. Social organisation and behaviour of muskoxen (*Ovibos moschatus*) on Bathurst Island, N.W.T. Ph.D. Thesis, Univ. Alberta, Edmonton. 212p.

Henry, G., Freedman, B. and Svoboda, J. 1986. Survey of vegetated areas and muskox populations in east central Ellesmere Island. Arctic: 39 (1) 78–81.

Hubert, B.A. 1977. Estimated productivity of muskoxen on Truelove Lowland. In: Bliss, L.C. 1977. Truelove Lowland, Devon Island, Canada: A High Arctic ecosystem. The University of Alberta press. 714p.

Jingfors, K.T. 1980. Habitat relationship and activity pattern of a reintroduced Alaskan muskox population. Ms. Thesis, Univ. Alaska, Fairbanks. 116p.

_____ 1982. Seasonal activity budget and movements of a reintroduced Alaskan muskox herd. Journal of Wildlife Management 46: 344–350.

Leoni, G. 1985. Die Nahrungswahl des Alpensteinbockes (*Capra ibex*) auf alpinen Silikatrasen bei Davos. M.S. Thesis, Eidgenoessische Technische Hochschule Zuerich, Switzerland. In German.

Parker, G.R. and Ross, R.K. 1976. Summer habitat use by muskoxen (*Ovibos moschatus*) and Peary Caribou (*Rangifer tarandus pearyi*) in the Canadian High Arctic. Polarforschung 1: 12–25.

Parker, G.R. 1978. The diets of muskoxen and Peary caribou on some islands in the Canadian High Arctic. Canadian Wildlife Service. Occasional Paper 35: 1–21.

Pedersen, A. 1958. Der Moschusochs, *Ovibos moschatus*. Ziemsen Verlag, Wittenberg. 54p. In German.

Raillard, M. 1985. Die Nahrungswahl der Gemse auf alpinen Silikatrasen bei Davos. M.S. Thesis, Eidgenoessische Technische Hochschule Zuerich, Switzerland. In German.

Rapota, V. 1984. Feeding ecology of the Taimyr Muskoxen. In: Klein, D.R., White, R.G. and Keller, S. eds. Proc. First Int. Muskox Symp., Biol. Pap. Univ. Alaska Spe. Rep. No. 4.

Sittler, B. and Kempf, C. 1984. Activity pattern of muskoxen during continuous summer day light in northeastern Greenland. In: Klein, D.R., White, R.G. and Keller, S. eds. Proc. First Int. Muskox Symp., Biol. Pap. Univ. Alaska Spe. Rep. No. 4.

Thing, H. 1984. Food and Habitat Selection by muskoxen in Jameson Land, northeastern Greenland: A preliminary report. In: Klein, D.R., White, R.G. and Keller, S. eds. Proc. First Int. Muskox Symp., Biol. Pap. Univ. Alaska Spe. Rep. No. 4.

Thomas, D.C. and Edmonds, I.C. 1984. Competition between caribou and muskoxen, Melville Island, NWT, Canada. In: Klein, D.R., White, R.G. and Keller, S. eds. Proc. First Int. Muskox Symp., Biol. Pap. Univ. Alaska Spe. Rep. No. 4.

Turner, D. 1984. Aktivitaetsrythmen beim Reh (*Capreolus capreolus*). M.S. Thesis, Universitaet Zuerich, Switzerland. In German.

Wilkinson, P.F., Shank, C.C. and Penner, D.F. 1976. Muskox-caribou range relations on Banks Island, N.W.T. Journal of Wildlife Management. 40: 151–162.

DIET AND DISTRIBUTION OF COLLARED LEMMINGS AND MEADOW VOLES NEAR CHURCHILL, MANITOBA, CANADA

Peter A. Scott

Department of Zoology, University of Toronto, Toronto, Ontario, Canada M5S 1A1

Level: Ph.D.

Abstract

A trapping study of the distribution and abundance of collared lemmings (*Dicrostonyx groenlandicus*) was undertaken at Churchill, Manitoba during 1980. Lemmings were present in beach meadows and lichen-heath tundra and absent in fen-bog meadows. The density of mature female lemmings was compared to the density of mature female meadow voles (*Microtus pennsylvanicus*), shrub cover, rock cover, and relative soil moisture. Lemmings appear to aggregate around rock and possibly thermal contraction cracks. Foraging was observed on natural sod in terrariums and stomach contents of trapped lemmings were identified. A preference for willows (*Salix* spp.) and *Dryas integrifolia* was determined although these species are more abundant in areas where lemmings are absent. Since less forage is present in lemming habitat then other areas at Churchill, it is suggested that rock cover is most important for burrow sites. The presence of rock serves to improve drainage, increase depth of thaw in deep peat, and offer a stable structure in coarse beach sediments.

Key words: Churchill, Manitoba, *Dicrostonyx groenlandicus*, *Microtus pennsylvanicus*, diet, distribution.

Résumé

L'auteur a effectué une étude par capture de la répartition et de l'abondance des lemmings variables (*Dicrostonyx groenlandicus*) à Churchill, Manitoba, au cours de 1980. Les lemmings sont actifs dans les prés littoraux et la toundra à lichens et bruyères, mais absents des tourbières basses et prés marécageux. L'auteur a comparé la densité de population des femelles matures de lemming avec la densité de population des femelles matures de campagnol des champs (*Microtus pennsylvanicus*), la couverture d'arbrisseaux, les abris rocheux et l'humidité relative du sol. Les lemmings se rassemblent autour des rochers, et peut-être autour des fissures de contraction thermique. L'auteur les a observés à la recherche de nourriture sur le gazon naturel de terrariums, et a identifié leurs aliments par l'examen du contenu stomacal des lemmings capturés. Ils préfèrent grignoter les saules (*Salix* spp.) et les *Dryas integrifolia*, bien que ces espèces soient plus abondantes dans les régions où les lemmings sont absents. Comme l'habitat des lemmings à Churchill offre assez peu d'aliments, l'auteur estime que les rochers sont importants, car ils améliorent l'écoulement des eaux, augmentent la profondeur de dégel de la tourbe et offrent des abris solides parmi les sédiments grossiers.

Mots-clés: *Dicrostonyx groenlandicus*, *Microtus pennsylvanicus*, régime alimentaire, répartition, Churchill, Manitoba.

Introduction

Until recently, descriptions of the distribution of collared lemmings (*Dicrostonyx groenlandicus*) in North America have been rarely quantified. Fuller *et al.* (1975) examine the distribution of collared lemmings at Truelove Lowland, Devon Island and report that they appear most concentrated in peat polygons and rock piles. Mallory and Boots (1983) analyze the spatial distribution of 'lemming mats' on Devon Island and suggest that social concerns may be a contributing factor to the distribution. Batzli *et al.* (1983) document collared lemming distribution in peat polygons and dry tundra near Barrow, Alaska. Batzli and Pitelka (1983) suggest that the distribution of lemmings may relate to the distribution of food plants. Batzli and Jung (1980; Jung and Batzli, 1981) have tested the digestibility of forage of lemmings in Alaska and show that wet tundra grasses and sedges are deleterious to collared lemmings whereas willows (*Salix* spp.) are among the preferred and most digestible of forage. The preference for willows has been supported by Fuller *et al.* (1975) and Rodgers and Lewis (1985) studying diet selection in *Dicrostonyx* at Igloolik. Little documentation has resulted from studies at Churchill, the southern limit of this species, where collared lemmings have been trapped frequently.

Description of collared lemmings at Churchill by Merriam (1900) coincided with field studies of the Churchill population by Preble (1902). Preble (1902) concluded that collared lemmings lived mainly on "gravelly ridges" and "old raised sea beaches". Later studies began after development of the railway to Port Churchill in 1929. Small mammal studies at Churchill by Shelford (1943), Smith and Foster (1957), and Wrigley (1974) are focused on concepts of population cycling in numbers. These studies attempt to decribe poorly defined populations from published and unpublished collecting trips as well as reports from trappers and local naturalists. Shelford and Twomey (1941) describe the tundra communities in some detail and evaluate the relative distribution of mammals. Smith and Foster (1957) briefly report some known dietary preferences for *Arctostaphylos* spp., *Dryas integrifolia*, and *Salix Richardsonii*. A study by Brooks (1970) indicates a greater range of forage as acceptable and describes some habitat variables during a period of high population density at beach-fenbog sites. Since the latest reported study of lemmings at Churchill was apparently in 1973 (Wrigley, 1974), the purpose of this study is to examine the current status of collared lemmings in the traditional study areas and to relate their distribution to the distribution of food plants.

Methods

A literature review and a field survey were used to define the plant communities in the Churchill region. On the basis of relative plant frequencies, four zones were classified: 1) tundra beach meadows, 2) lichen-heath tundra, 3) fen-bog meadows, and 4) open forest. Within three of these zones, nine sites were chosen for study (Figure 1); three on lichen-heath tundra (sites 1, 4, 5); three on tundra beach meadow

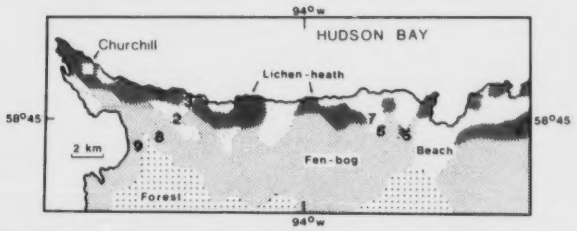


Figure 1. A map of the study area showing the four major plant zones found: open forest, lichen-heath, beach meadows, and fen-bog meadows. The location of the study sites are marked 1 through 9.

(sites 2, 3, 7); two in fen-bog meadow (sites 8, 9); and one site within a beach meadow/fen-bog mosaic (site 6).

A population census was undertaken by removing the small mammals from the sites. Trapping began during snowmelt in early June of 1980. In the fen-bog meadows, up to 150 snap-traps were placed along a measured transect in order to capture the resident small mammals. The spacing of each trap was dependent on the density of small mammal burrows (Fuller *et al.*, 1975) although trap distance ranged from 1 to 5 m. The traps were baited with a mixture of rolled oats and peanut butter, and checked daily at 0800 h and sunset. After 6 days, the traps were relocated 10 m onto a parallel transect. This process was repeated four times for a total of 3600 trap nights.

At sites not found in the fen-bog meadows, the number of small mammals was low enough to remove all of them. Snap-trapping at these sites during June also included live trapping with Sherman-type traps and hand capture. All of the burrow entrances were then either crossed with a strand of spider web or shoots of grass. From 1 July until September the sites were periodically monitored for evidence of fresh burrowing or intrusions into established burrows.

Each animal collected was examined in order to determine the species, weight, and sex. The stomachs of the collared lemmings were removed and the contents were washed into a Petri dish with 5 ml of distilled water. The material was mixed thoroughly and 5 samples from each stomach were placed on slides for microscopic examination. The stomach contents were compared to a reference collection (described below).

Eight live lemmings were placed in plywood terrariums measuring 60 × 60 × 45 cm. A lining of sod containing vegetation found at lemming capture sites was placed in the terrariums and replaced approximately every 3 days. The lighting and temperature were natural. Feeding habits were observed.

Eight live lemmings were starved for 24 hours and fed one of the eight most commonly eaten species of plants. After 30 minutes the lemmings were killed and the stomachs were removed. Samples from the stomachs were mounted on slides as a reference collection.

The plant distribution within each community was quantified by quadrat analysis of randomly chosen areas near the centre of each site. The frequency of occurrence of all vascular plants and lichens was recorded using quadrats arranged in a square of 5 × 5; each quadrat measured 10 × 10 cm and

TABLE 1
The frequency of occurrence of plants on representative sites: lichen-heath on rock outcrop (1A), in depression on rock outcrop (1B), lichen-heath (4), wet beach meadow (2), dry beach meadow (3), bench-fen-bog (6), and fen-bog meadows (9); plants with a frequency of occurrence greater than 0.01% are presented

	SITES WITHIN THE STUDY AREA						
SPECIES	1A	1B	4	2	3	6	9
Salix planifolia	12.5	51.2	30.0	28.6	----	5.5	63.0
S. lanata	2.7	----	----	6.8	----	----	----
S. reticulata	2.1	19.8	2.2	30.2	----	2.5	44.2
Dryas integrifolia	7.5	0.6	45.5	19.0	76.1	35.0	0.4
Andromeda polifolia	----	----	----	----	----	----	25.8
Empetrum nigrum	84.1	60.2	15.1	----	----	0.8	47.0
Ledum decumbens	27.2	2.2	2.0	----	----	----	35.3
Rhododendron lapponicum	2.6	21.6	18.6	17.6	----	28.8	----
Betula glandulosa	3.5	----	0.3	1.0	----	----	17.3
Vaccinium uliginosum	5.2	16.0	1.7	1.8	0.3	4.3	29.7
V. vitis-idaea	39.2	11.8	14.3	----	----	----	0.3
Arctostaphylos rubra	7.5	17.4	27.5	14.8	4.6	10.5	----
Rubus chamaemorus	12.5	1.0	----	----	----	----	----
Hedysarum mackenzii	----	----	----	----	39.0	----	----
Hartsia alpina	----	----	----	----	----	----	3.4
Tofieldia pusilla	----	----	----	----	----	----	4.9
Scirpus caespitosus	----	----	----	----	----	9.8	----
Carex rupestris	----	----	12.0	82.2	76.8	----	----
C. scirpoidea	----	1.2	14.2	----	----	64.5	4.3
C. aquatilis	----	8.6	----	----	----	19.6	23.8
Equisetum arvense	----	13.4	----	----	----	----	17.7
Cetraria nivalis	0.3	----	----	----	----	----	----
C. cucullata	16.3	----	14.1	----	0.3	----	----
Ochroleucia upsaliensis	13.2	----	15.8	5.2	----	----	----
Alectoria nitidula	17.0	----	23.0	----	----	----	----
Moss spp.	----	78.4	----	----	----	35.8	87.6
NUMBER OF QUADRATS	400	200	600	300	500	600	200

was subdivided into 9 equal squares (Kershaw, 1973). At least 200 quadrats were examined at each site. Three circular 1 m sub-sites were selected randomly and the level of the water was recorded, as well as the depth to permafrost. Three samples of soil were collected from each site, 48 hr from the last period of precipitation. The soil samples were dried to a constant weight at 80°C and the soil moisture (by weight) was recorded. From the centre of each site, 10 transects of 65 m were arranged in a radial pattern at approximately 36° angles to each other (Abramsky, 1981). The percent cover of rock, deciduous shrubs and dwarfed conifers (*Picea glauca*) was quantified. (A shrub is considered a deciduous woody plant that forms the canopy. This was usually *Salix* spp. and occasionally trace amounts of *Betula glandulosa* were included.)

In order to measure the three dimensional surface area of a study site, perimeter measurements included topographical features.

Results

Description of plant communities

From community studies and quadrat analysis (Table 1), the nine trapping sites are found within three major plant zones (Figure 1) that are described below.

Tundra beach meadows are a beach succession occurring on sand based areas with less than 5 cm of peat. Ground thaw begins in June and exceeds 2 m by September. On the younger ridges, *Elymus arenaris* and *Honkeyna peploides* are dominant. On the older ridges, *Dryas integrafolia*, *Carex rupestris*, and *Hedysarum mackenzii* become prevalent with

TABLE 2
The characteristics for all nine study sites at Churchill

Churchill									
ZONE	LICHEN-HEATH			BEACH			BH/FB*	FEN-BOG	
SITE NUMBER	1	4	5	2	3	7	6	8	9
AREA (Ha)	1.00	0.30	0.47	1.60	4.80	0.65	32.00	0.24	0.32
No. MATURE FEMALE									
LEMMINGS	13	3	7	3	3	7	9	---	---
VOLES	7	3	---	---	---	---	10	14	22
DENSITY* MATURE FEMALE									
LEMMINGS	13.0	10.0	14.9	1.9	0.6	10.8	0.3	---	---
VOLES	7.0	10.0	---	---	---	---	0.3	>58	>68
% COVER OF									
SHRUB	7.5	5.0	5.1	1.5	tr*	---	tr	18.0	65.0
TREE	tr	---	tr	tr	tr	---	2.0	15.1	8.3
ROCK	21.4	15.0	35.0	1.5	---	20.0	1.0	1.0	0.5
SOIL MOISTURE (gm)	76.1	78.3	74.5	55.7	25.0	38.7	40.0	87.4	74.3
TYPE	peat	peat	peat	sand	sand	sand	sand	peat	peat

* beach-fen-bog; * ha^{-1}; * trace

some *Arctostaphylos rubra* and *Salix calcicola* or *S. vestita*. In the poorly drained areas of the meadow, *Carex subspatheca* and *Puccinellia phryganodes* are prevalent early in the development stages, gradually being replaced by *Dupontia fisheri*, *Calamagrostis neglectis* and *Carex aquatilis* in the later stages. Other descriptions are provided by Scoggan (1959).

Lichen-heath tundra communities occur mainly on rock in the study area, although peat accumulation over most substrates climax in lichen-heath (Shelford and Twomey, 1943). Ground thaw can exceed 5 m on the Churchill Quartzite outcrop but rarely exceeds 60 cm where rock is absent. A complex mosaic of vegetation includes *Empetrum nigrum*, *Vaccinium uliginosum*, *V. vitis-idaea*, *Arctostaphylos rubra*, *Salix reticulata*, *S. lanata*, *S. arctophila*, *S. planifolia*, as well as lichens such as *Cetraria nivalis*, *C. cucullata*, *Cornicularia divergens*, *Alectoria nigricans*, and *A. nitidula*. Other descriptions are provided by Shelford and Twomey (1943) and Scoggan (1959).

Fen-bog meadows are based on clay and glacial till resulting in poor drainage and differential peat accumulation over time. Annual ground thaw exceeds 1 m. Hummocks appear to develop in slightly elevated and thus better drained areas. Consequently, plant communities coincide with height above the water table and lichen-heath occurs on the top of the larger mounds. Within the fen-bog floor, *Carex aquatilis* dominates with *Calamagrostis canadensis* and various species of *Moss*, and *Salix* in shrub form occurring in the sheltered areas. A more complete description of community development is given by Ritchie (1957).

Small mammal trapping

Since juveniles tend to be mobile and males can include more than one female within their home range (Brooks and Banks, 1971), the number of mature female collared lemmings and meadow voles was used for calculations of density (mature animals weighing more than 25 gm and 15 gm respectively, as this appears to approximate sexual maturity). For captures at the fen-bog sites a minimum known density was calculated.

TABLE 3
The correlation coefficients between density of mature female lemmings and density of mature female meadow voles, percent cover of rock, percent cover of shrub, and the relative soil moisture by weight for all 9 sites

VARIABLES	VOLE DENSITY	SHRUB COVER	SOIL MOISTURE	ROCK COVER
SHRUB COVER	.9424**	-----		
SOIL MOISTURE	.5657	.4784	-----	
ROCK COVER	-.4085	-.3473	.2694	-----
LEMMING DENSITY	-.4617	-.4090	.2592	.9698**

** Significant correlations ($p < .001$).

Collared lemmings were trapped from sites 1 through 7 and meadow voles were trapped from sites 1, 4, 6, 8 and 9 (Figure 1). The quantified habitat characteristics include soil type, soil moisture, rock cover, tree cover, and shrub cover. The general characteristics and small mammal densities of the nine sites are presented in Table 2.

Each site was typical of the respective communities. The three lichen-heath sites were up to 1 ha in size. The density of mature female lemmings ranged above 10.0 ha^{-1} and mature female voles were found at lower densities. Shrub cover was just over 5% and tree cover was minimal. Rock cover extended over 15 to 35% of the ground and usually more than 75% of the weight of the peat was water.

The three beach sites ranged up to 4.8 ha in size. There was a large range of mature female lemming densities up to 10.8 ha^{-1} and mature female voles were not found. Shrub cover was less than 1.5% and only traces of tree cover existed (<.01%). Rock cover was nonexistent on one site and ranged to 20%. The soil moisture by weight of the sand ranged from 55% (saturated) to 25% (dry).

A single beach-fen-bog site of 32 ha was examined with mature female voles and lemmings found at similar low densities. There was minimal shrub cover, 2% tree cover and very little rock cover. The sand contained 40% moisture by weight.

The two fen-bog sites were less than 0.5 ha in size and had extremely high densities of meadow voles while lemmings were not found. Shrub cover varied from 18 to 65% and tree cover was more extensive than at other sites. Rock cover was minimal and the moisture by weight of the peat ranged from 87% (saturated) to 74% (dry).

Many of the monitored burrows were entered after the trapping period. Several of these invasions were attributed to weasels (*Mustela ermina*) and in one instance a fox (*Alopex lagopus*) had been digging. In two instances at both sites 1 and 2, and one instance at site 3, burrows were entered by collared lemmings. However they are not considered to be resident during June as the appearance of these lemmings occurred more than 30 days after the last period of trapping.

Other invasions of burrows involved other species of small mammals (ie. *Clethrionmys gapperi*).

Density of female collared lemmings at all study sites was correlated with site characteristics (Table 3). There is a strong correlation between density of voles and shrub cover ($p < .001$). There is a strong positive correlation between density of lemmings and cover of rock ($p < .001$). Within the correlation analysis there are some notable associations. Correlations involving both density of lemmings with density of voles, and with cover of shrubs are negative. Correlation between the density of voles and cover of rock is also negative.

Food preferences

Stomach contents of lemmings were categorized by cell structure and identified to species where possible. The contents consisted of mainly *Dryas integrifolia*, *Salix* spp. (*S. lanata*, *S. reticulata*, and *S. planifolia* and/or *S. arctophila*) with less than 20% unidentified dicots, grasses, sedges, and algae. There was difficulty in quantifying the stomach contents because of large differences in the size of food particles, among other things (see Hansson, 1970; Neal and Owen, 1973).

Observations of feeding habits indicate the preferred forage as *Salix reticulata*, *S. planifolia*, *S. arctophila*, *Dryas integrifolia* (especially flowers), *S. lanata*, *Arctostaphylos rubra*, *Bartsia alpina*, and *Castilleja raupii* flowers (in descending order). The first six species were eaten consistently and other species were eaten secondarily depending on the availability. These preferences are similar to those reported by Smith and Foster (1957) and Brooks (1970) for collared lemmings at Churchill.

Discussion

The meadow vole, found in sympatry with collared lemmings at Churchill, is an inhabitant of the forests and forest meadows of temperate North America (Cameron, 1964; Grant, 1975). Bundles of 'cuttings' near meadow vole burrows at Churchill indicate a preference for *Carex aquatilis* and *Dupontia fisherii*. Large numbers of meadow voles were found in fen-bog meadows (sites 8 and 9), as reported by Brooks (1970). The transects in site 9 start at the forest and progress west through zones of *Betula glandulosa*, *Salix* spp., grass and sedge meadows to the tidal flats of Hudson Bay. The transects of site 8 extend north from the treeline through a zone of *Salix* spp., a grass and sedge meadow zone, and through a wet, hummocky meadow (Table 1). In both sites, the largest number of meadow voles was estimated at the transition from the meadow zone to the willow zone. Although correlation analysis reveals a strong positive relationship between the density of meadow voles and the percentage cover of shrubs (Table 3), when the shrub cover exceeds 60% and grasses and sedges become sparse, the signs of vole activity decline.

At sites 1, 4 and 6, meadow vole trapping was successful in sparsely distributed depressions found beneath spruce trees or around tundra ponds. These wet areas are covered in moss, contain a high concentration of meadow vole burrows relative to the surrounding tundra meadow, a high frequency of grasses and sedges, and a cover of willow or birch shrubs (ie. site 1a, Table 1).

Although lemmings occurred in much lower peak densities than voles (Table 2), three lichen-heath tundra sites (1, 4 and 5) and a single beach meadow site (7) had the highest densities of lemmings (13.00, 10.00, 14.89, 10.77 mature females ha^{-1} respectively). As a food source, *Dryas integrifolia* is far more abundant on the beach meadows than on the lichen-heath tundra. *Salix lanata*, *S. arctophila* and *S. planifolia* occur more frequently in fen-bog meadows (Table 1). Lichen-heath develops on elevated features, such as hummocks, palsas, and peat plateaus within the fen-bog meadows. On average 42% of the surface of these features is comparable to the lichen-heath tundra and 40% of the fen-bog meadow is covered with elevated features. The surface area of the fen-bog meadows in the study region is 43.86 km^2 and thus, 16.8% or 7.37 km^2 are covered with lichen-heath. The total area of lichen-heath tundra classified is 7.97 km^2. During this study, only 52% of the total lichen-heath in the Churchill region was occupied by lemmings. Furthermore, the dominant plants of *Empetrum nigrum*, *Vaccinium vitis-idaea*, and *Ledum decumbens* (Table 1) are not preferred food plants (Brooks, 1970) and Jung and Batzli (1981) have shown that *L. decumbens* is deleterious to collared lemmings.

The major food sources for lemmings are most abundant and close by in the fen-bog meadows where there is greater shrub cover than on the lichen-heath tundra sites (Table 2). Brooks (1970) reports a large number of lemmings at site 6 (beach-fen-bog) during 1967, and much fewer numbers, comparable to this study, during 1968 and 1969. During the early 1980's, most of the burrow entrances were at or below the level of the water table. It appears that the droughts of 1965 and 1966 (Canada Climate Centre, Downsview, Ontario) resulted in a lowered water table, enabling colonization and a subsequent population explosion. The water table would have been replenished by late 1967 or the spring of 1968. The flooding would have caused a population decline since the elevated peaty features found in the fen-bog meadows have permafrost intrusions and ice lenses which greatly reduce the volume of peat available for burrowing.

On the beach meadow where rock was absent (site 3), mature female lemmings were rare (0.63 ha^{-1}) but relatively abundant (10.77 ha^{-1}) at site 7 where rock was more abundant (Table 2). The common characteristic between site 7 and the lichen-heath sites, is a relatively high percentage of rock (Table 2). Although thaw depth may exceed 2 m and the soil is relatively dry on beach sites, burrows are more frequent around large rocks that tend to stabilize the soil. The large piles of sand at burrow entrances show that considerable maintenance is required, indicating that the burrows probably collapse frequently.

On lichen-heath tundra, lemming burrows are found around rock and also found along thermal contraction cracks in the deep (20–80 cm) peat between rock outcroppings. The use of thermal contraction cracks by lemmings has been reported by Fuller *et al.* (1975) and Batzli *et al.* (1983). The burrows frequently lead to a chamber or nest within a pile of boulders beneath the peat.

Lemmings burrow by digging into the soil up to 1 m deep and then extend the burrows several metres horizontally, branching into what appears to be specialized compartments, air shafts, and secondary entrances (see Preble, 1902; Brooks,

1970). The subterranean habits of lemmings require large volumes of thawed, unsaturated soil. Most surficial material in Churchill is either frozen or saturated for most of the year (Dredge, 1979). Storm beaches, rock piles, and rock outcrops that occur on the tundra may offer an advantage in four ways: 1) Cracks within and spaces between the rock can be used temporarily to hide from predators; 2) The areas around large boulders and within settled rock piles offer a nest site protected from extreme weather conditions and physical disturbances; 3) Rock can increase the volume of soil available for burrowing by sheltering vegetation from the wind leading to greater peat accumulation as well as trapping wind swept soils; 4) In areas where there is an insulating layer of peat established, boulders can serve to conduct heat into the active layer and improve drainage, increasing the volume of soil available for tunnels and burrows.

Radio tracking studies reveal that lemmings spend up to 70% of the time engaged in travelling and other activities outside the main burrow (Banks and Brooks, 1971). Lemmings may travel a kilometre or more, searching out active burrows in order to locate mates, among other things (Mallory and Boots, 1983; Brooks, 1970). A strategy of being highly mobile, particularly where individuals are sparsely distributed, may result in foraging patterns that show little relationship between a lemming burrow and the surrounding plant community.

Conclusions

At Churchill, Manitoba, *Microtus pennsylvanicus* inhabit the wet sedge and grass areas, aggregating around food plants and under shrub cover.

It appears that *Dicrostonyx groenlandicus* prefer forage of primarily *Salix* spp. and *Dryas integrifolia* during the summer season. This preference is less diverse than collared lemmings at Igloolik (Rodgers and Lewis, 1985) where the climate is harsher and vegetation is sparse. Unlike the study by Batzli *et al.* (1983) in Alaska, collared lemming burrows at Churchill are not found where forage is most abundant. Lemmings are found on open ground with less cover, less forage, deeper and more stable soils than wetland sites. Lesser amounts of the lush arctic vegetation at Churchill is apparently adequate forage. The distribution of collared lemmings is related to rock cover and perhaps thermal contraction cracks.

Acknowledgments

I would like to thank M. Turner for field assistance, R. Brooks and J. Malcolm for their cooperation in the field, M. Berrill and P. Boag for helpful discussions, the Churchill Northern Studies Centre and particularly W. Erickson for use of the facilities, and R. Hansell and C. Bentley for helpful comments on the manuscript. Funds were provided by an N.S.E.R.C. grant to R. Hansell and two Northern Scientific Training Grants to the author.

References

Abramsky, Z. 1981. Habitat relationships and competition in two Mediterranean *Apodemus* spp. Oikos 36:219-225.

Batzli, G.O. and Jung, H.-J.G. 1980. Nutritional ecology of microtine rodents: resource utilization near Atkasook, Alaska. Arctic and Alpine Research 12:483-499.

Batzli, G.O. and Pitelka, F.A. 1983. Nutritional ecology of microtine rodents: food habits of lemmings near Barrow, Alaska. Journal of Mammalogy 64:648-655.

Batzli, G.O., Pitelka, F.A. and Cameron, G.M. 1983. Habitat use by lemmings near Barrow, Alaska. Holarctic Ecology 6:255-262.

Brooks, R.J. 1970. Ecology and acoustic behavior of the collared lemming, *Dicrostonyx groenlandicus* (Traill). Unpublished Ph.D. Thesis, University of Illinois, Urbana, Illinois.

Brooks, R.J. and Banks, E.M. 1971. Radio-tracking study of lemming home range. Communications in Behavioural Biology 6:1-5.

Cameron, A.W. 1964. Competitive exclusion between rodent genera *Microtus* and *Clethrionmys*. Evolution 18:630-634.

Dredge, L.A. 1979. Thaw depths and permafrost in polygonal peat terrain, Hudson Bay Lowland, Manitoba. Geological Survey of Canada Paper 79-1C:23-26.

Fuller, W.A., Martell, A.M., Smith, R.F.C. and Speller, S.W. 1975. High arctic lemmings (*Dicrostonyx groenlandicus*) I. Natural history observations. Canadian Field-Naturalist 89:223-233.

Grant, P.R. 1975. Population performance of *Microtus pennsylvanicus* confined to woodland habitat, and a model of habitat occupancy. Canadian Journal of Zoology 53:1447-1465.

Hansson, L. 1970. Methods of morphological diet micro-analysis in rodents. Oikos 21:255-266.

Jung, H.-J.G. and Batzli, G.O. 1981. Nutritional ecology of microtine rodents: effects of plant extracts on the growth of arctic microtines. Journal of Mammalogy 62:286-292.

Kershaw, K.A. 1973. Quantitative and dynamic plant ecology. London: Edward Arnold. 308 p.

Mallory, F.F. and B.N. Boots. 1983. Spatial distribution of lemming mats in the Canadian High Arctic. Canadian Journal of Zoology 61:99-107.

Merriam, C.H. 1900. Descriptions of twenty-six new mammals from Alaska and British North America. Proceedings Washington Academy of Science 2:13-30.

Neal, B.R. and Owen, B.D. 1973. A comparison of faecal and stomach contents analysis in the meadow vole (*Microtus pennsylvanicus*). Canadian Journal of Zoology 51:715-721.

Preble, E.A. 1902. A biological investigation of the Hudson Bay region. North American Fauna 22:1-140.

Ritchie, J.C. 1957. The vegetation of northern Manitoba. II. A prisere on the Hudson Bay Lowlands. Ecology 38:429-435.

Rodgers, A.R. and Lewis, M.C. 1985. Diet selection in arctic lemmings (*Lemmus simbericus* and *Dicrostonyx groenlandicus*): food preferences. Canadian Journal of Zoology 63:1161-1173.

Scoggan, H.J. 1959. The native flora of Churchill, Manitoba. Ottawa: National Museum of Canada. 51p.

Shelford, V.E. 1943. The abundance of the collared lemming (*Dicrostonyx groenlandicus* (Tr.) var. *Richardsonii* Mer.) in the Churchill area, 1929 to 1940. Ecology 24:472-484.

Shelford, V.E. and Twomey, A.C. 1941. Tundra animal communities in the vicinity of Churchill, Manitoba. Ecology 22:47-69.

Smith, D.A. and Foster, J.B. Notes on the small mammals of Churchill, Manitoba. Journal of Mammalogy 38:98-115.

Wrigley, R.E. 1974. Ecological notes on animals of the Churchill Region of Hudson Bay. Arctic 27:201-213.

EFFECT OF NATIVE HARVEST ON THE POPULATION DYNAMICS OF THE NORTHERN MUSKRAT (*ONDATRA ZIBETHICUS SPATULATUS*)

Mark R. Simpson

Department of Zoology, University of Alberta, Edmonton, Alberta T6G 2E9

Level: Master's

Abstract

The effect of native harvest on muskrat populations was studied in 1985 and 1986. Populations were monitored at Old Crow Flats on trapped and untrapped areas using mark-recapture livetrapping techniques and carcass analysis.

There was no significant difference in the mean number of young produced per female between trapped and untrapped areas. There was no evidence of precocial breeding (breeding by young of the year). Significantly more individuals immigrated into harvested areas and became residents than in unharvested areas. Lack of immigration into untrapped areas was attributed to overcrowding, creating a fence effect where normal dispersal movements were blocked.

A management plan for the harvest of muskrats is suggested which advises that patches of trapped and untrapped areas should be maintained, the latter to act as refuges from which dispersing individuals can 'seed' trapped areas.

Key words: Muskrats, harvest, recruitment, Old Crow.

Résumé

La plus grande région productrice de fourrures de rat musqué au Yukon est Old Crow flats, un grand marécage de 518 000 ha, habitat préféré de ces animaux. L'auteur a étudié, en 1985 et 1986, l'effet du piégeage par les Autochtones sur les populations de rats musqués. Les fluctuations de ces populations ont été suivies dans les aires non piégées et dans des aires de piégeage, grâce à des techniques de marquage des animaux capturés vivants et piégés ensuite, et par l'étude des carcasses.

La comparaison des aires de piégeage et non piégées a indiqué qu'il n'existe pas de différence sur le plan de la reproduction. L'auteur n'a pas détecté de reproduction précoce (par les jeunes de l'année), ni d'écart entre le nombre moyen de jeunes par femelle de chacune des deux zones. Un nombre plus important d'individus se sont établis dans les aires de piégeage que dans les aires non piégées. L'auteur attribue ce fait à la surpopulation des aires non piégées, laquelle crée des obstacles à la dispersion normale des rats musqués.

L'auteur propose un plan de gestion de la capture des rats musqués par les Autochtones, lequel se fonde sur des modifications à la stratégie actuelle de piégeage. Il faudrait maintenir des aires de piégeage et des aires non piégées; ces dernières serviraient de refuges à partir desquels la dispersion des rats musqués pourrait repeupler les zones de piégeage.

Mots-clés: Rat musqué, capture, piégeage, reproduction, émigration, Old Crow.

Introduction

Old Crow Flats is a unique area of the Canadian Arctic. Despite the extreme conditions (Stevens, 1953) it is a highly productive wildlife habitat. The most abundant mammalian species of the area is the muskrat *Ondatra zibethica*, which is exploited for its pelt. The muskrat harvest from Old Crow Flats constitutes 75% of the total Yukon territory harvest of this species, as well as 75% of the Old Crow natives' total fur harvest. The Old Crow fur harvest of 10,000–30,000 muskrats has been valued up to $87,000/annum (Slough, 1982). Furthermore, muskrat trapping is also important to many native residents of Old Crow as part of their traditional lifestye.

Despite the obvious ecological, economic and social importance of the exploitation of this species, few studies have examined the effects of harvest pressure on population dynamics (Parker and Maxwell, 1984; Smith *et al.*, 1981) and none have studied northern populations. Presently the resiliency of muskrat populations to the effects of harvest (Errington, 1963; Smith *et al.*, 1981) is thought to occur by any of four mechanisms; increased precocial breeding (Parker and Maxwell, 1984), increased litter production by adults (Olsen, 1959), increased survival of remaining individuals (Errington, 1963), or by increased immigration (Errington, 1940). My objective is to examine the effect of harvest on muskrat population dynamics by testing the above hypotheses.

Study area and methods

The Old Crow Flats is a 518,000 ha lacustrine basin located in the northern Yukon (140°05′west, 68°05′north). This area has approximately 389,000 ha of small thermokarst lakes which is suitable muskrat habitat due to the presence of abundant submergent vegetation dominated by *Potomogedon* and *Myriophyllum* sp. Emergent vegetation is absent.

Four study sites were selected on the Old Crow Flats, two which were subjected to removal trapping to simulate the native harvest and two which were not harvested. Each trapped area was within 1 km of an untrapped area, and all areas were located within a 10 km radius. Prior to, and following the harvest treatment, each area was livetrapped using Tomahawk livetraps. Two areas were trapped at any one time, one of each harvest treatment. Trapping was initiated in April and early May, and continued until June 15 of each year. It then resumed in late July, and proceded until September. Each area was trapped until 70% of the animals were recaptured. Traps were placed, during ice-free periods (June–Sept.) on feeding sites along the shore of the lakes and in the vicinity of burrow openings. During the periods of ice cover (April and May) traps were placed on the feeding site within the pushup itself and then covered (Stevens, 1953).

Traps were checked every eight hours, and remained set for the entire twenty four hour period. Captured animals were marked with a numbered #1 monel ear tag (National Tag Comp.), weighed with a Pesola spring scale, sexed, aged by pelage characteristics and then released. An index of immigration was calculated by dividing the number of new adults captured (adults not enumerated previously) by the area of the study site (in ha).

Muskrats were removed on the harvested areas during April, May and June of 1985 and 1986, [illegible] trapping muskrats in their pushups with #1 Victor longspring traps, and by shooting. At least 50% of the animals known to be alive from livetrapping were removed on both areas. For each harvested animal its tag number and age was recorded. Weight was measured to the nearest 5 grams using a Pesola spring scale. Sex and reproductive condition was also recorded, as was the number of embryos/placental scars present. In the fall of 1986, adult females were sacrificed on all four areas, and their uteri examined for placental scars. The number of scars/female and the number of young livetrapped/adult female were used as measures of productivity.

TABLE 1
Number of new adults (captured for first time), and immigration index (new adults/size of area) for harvested and unharvested areas.

	[illegible]	[illegible]
Harvested	[illegible]	[illegible]
	[illegible]	[illegible]
Unharvested	[illegible]	[illegible]
	[illegible]	[illegible]

Results

Comparison of placental scar counts between trapped and untrapped areas indicated no significant difference ($t = 0.433$, $P = 0.668$) in the number of juveniles produced per female. Litter size (mean +/− SD) was 9.2+/−2.2 and 7.7+/−2.4 on trapped and untrapped areas respectively. None of the 101 juveniles livetrapped in 1986 or the 283 juveniles livetrapped in 1985 had any placental scars or embryos. More new adults were tagged on trapped than untrapped areas (Table 1). The immigration index for the two untrapped areas were 0.75 and 0.33, whereas for the trapped areas these indices were 1.6 and 1.7 (Table 1). The differences were significant between treatment means ($t = 5.143$, $p = 0.036$).

Discussion

I rejected the compensatory reproduction and precocial breeding hypotheses as mechanisms of population resiliency in northern muskrat populations. I found that trapped areas were repopulated by immigrating individuals, thus supporting the immigration hypothesis.

Precocial breeding and compensatory reproduction have been frequently reported in muskrat populations. Parker and Maxwell (1984) found precocial breeding occurred in 5% of juveniles sampled. Similarly, Errington (1963) found levels of precocial breeding as high as 5.3%. However, Smith *et al.* (1981), in accordance with our findings, found precocial breeding did not occur in their study population. Presently it is questionable if precocial breeding in fact occurs in muskrats at all with the findings of Moses and Boutin (1986).

Variation in muskrat litter size or the number of litters in response to mortality has been reported by Olsen (1959) and Errington (1951). This compensatory reproduction has been proposed as a major mechanism of population regulation in muskrats. However, litter size in the Old Crow population did not display any significant differences between the treatment areas, as was found by Parker and Maxwell (1984) in New Brunswick. Litter size on Old Crow Flats from placental scars for all females analyzed indicated the mean production per female on the flats was 8.47+/−2.5 which is not significantly different from the 7.8+/−3.6 reported by Ruttan (1974) in another region of Old Crow Flats. However, annual production/female is significantly lower on Old Crow Flats when compared to more southern populations of muskrats where two to three litters per year are produced (Perry, 1982). Therefore, though compensatory reproduction may be a viable mechanism for population maintenance in southern populations of muskrats, the constraints imposed by the length of reproductive season in northern environments make it unlikely here.

As indicated by Errington (1940) immigration into areas of reduced density may compensate for trapping mortality. In harvested areas, the appearance of new adults during the spring dispersal (Errington, 1940) allows for repopulation of these areas without altering the reproductive schedules of those present. Mathiak and Linde (1954) indicated that repopulation of muskrat vacant habitat through immigration was unimportant on Horicon Marsh in Wisconsin. Their study indicated that less than one percent of tagged refuge individuals moved outside their area of capture. However, Parker and Maxwell (1984) estimated 20% of the spring population immigrated from trapped compounds in New Brunswick, indicating that spring dispersal may be of substantial benefit to areas of reduced density. The influx of adult muskrats into the trapped areas of my study indicate refuges may have a significant impact on population maintenance. This would be especially important in a population where the growing season is reduced to a period which makes production of multiple litters or precocial breeding impossible. The lack of immigration into untrapped areas can possibly be attributed to a density dependent response, whereby the higher density creates a fence effect blocking normal dispersal movements.

To summarize, the compensatory reproduction and precocial breeding hypotheses were rejected as mechanisms of population resiliency to harvest. In northern environments where the growing season may limit reproduction, dispersal and immigration are mechanisms by which areas of low density can be repopulated. Therefore, trappers on the Old Crow Flats should leave some areas as refuges from which dispersing individuals can 'seed' areas which have been trapped. This trapping regime is different from that presently utilized, where the native harvest is uniformly distributed within their trapping grounds.

Acknowledgments

I would like to thank my supervisor, S. Boutin, for his support and advice. As well, thanks must go to Brian Slough and the Yukon Wildlife Branch for their financial support. Support was also obtained from Northern training grants to M.R. Simpson, an NSERC Northern Supplement to S.A. Boutin, and Northern training grants.

References

Errington, P. 1940. Natural restocking of muskrat-vacant habitats. J. Wildl. Manage. 4(2):173–185.

_____ 1951. Concerning fluctuations in populations of the prolific and widely distributed muskrat. Amer. Nat. 85:273–292.

_____ 1963. Muskrat populations. Ames: Iowa State University Press. 665 p.

Mathiak, H.A. and A.F. Linde. 1954. Role of refuges in muskrat management. Tech. Wildl. Bull. 10. Wisconsin Conserv. Dept.

Moses, R. and S.A. Boutin. 1986. Molar fluting and pelt primeness techniques for distinguishing age classes of muskrats: a reevaluation. Wildl. Soc. Bull. 14:403–406.

Olsen, P.F. 1959. Muskrat breeding biology at Delta, Manitoba. J. Wildl. Manage. 23:40–53.

Parker, G.R. and J.W. Maxwell. 1984. An evaluation of spring and autumn trapping seasons for muskrats, *Ondatra zibethicus*, in eastern Canada. Can. Field Nat. 98: 293–304.

Perry, H.R. Jr. 1982. Muskrats. In: Chapman, J.A. and G.A. Feldhamer (Eds.). Mammals of North America. Baltimore: John Hopkins University Press. pp. 282–325.

Ruttan, R.A. 1974. Muskrat studies on Old Crow Flats Yukon Territory. 1972. In: Ruttan, R.A. and D.R. Wooley (Eds.). Studies of furbearers associated with proposed pipeline routes in the Yukon and Northwest Territories. Arctic Gas Biological Report Series vol. 9.

Slough, B.G. 1982. Preliminary investigation of the muskrat population and harvest of Old Crow Flats and Northern Yukon. Unpublished manuscript.

Smith, H.R., Sloan R.J. and G.S. Walton. 1981. Some management implications between harvest rate and population resiliency of the muskrat (*Ondatra zibethicus*). In: Chapman, J. and D. Pursley (Eds.). World Furbearer Conf. Proc. Aug. 2–11, 1980.

Stevens, W.E. 1953. The northwestern muskrat of the Mackenzie Delta, Northwest Territories, 1947–48. Can. Wildl. Serv. Wildl. Manage. Bull. Series 1: 8. 47 p.

AGONISTIC INTERACTIONS AND FORAGING STRATEGIES OF CAPTIVE AND WILD ARCTIC FOX

L.G. Wakely and F.F. Mallory

Department of Biology, Laurentian University, Sudbury, Ontario P3E 2C6

Level: L.G. Wakely, Master's

Abstract

In July 1985, six arctic fox (*Alopex lagopus*) kits were lived-trapped at Eskimo Point, N.W.T. and transported to the Dr. Paul Field Animal Research Facility, Laurentian University, Sudbury, Ontario. Fox activity was filmed, at den sites during July and August and while foraging during November, 1985. Behaviours video taped under controlled experimental conditions are being compared to behaviours observed in the wild.

Basic husbandry, growth rates, moult patterns, feeding hierarchies, social interactions, caching, scent marking and activity patterns are being studied in both summer and winter months. Preliminary data suggest that kit feeding hierarchies are linear and correlated with body weight. Scent marking appears to be strongly correlated to the obtainment rather than to the caching of food. Scent marking is also being studied with respect to various stimuli including novel enclosures, raised structures (hummocks), conspecific faeces and neutral objects. The social interactions of breeding and non breeding pairs are being studied and preliminary data suggest that behavioural changes occur during the breeding season. Changes in photoperiod appear to play a role in mediating behavioural changes, as well as the summer and winter morphs.

Key words: Arctic fox, behaviour, *Alopex*.

Résumé

En juillet 1985, on captura six renardeaux arctiques (*Alopex lagopus*) à Eskimo Point, T.N.-O., et on les envoya à la Station de recherches animales du Dr. Paul Field, à l'Université Laurentienne, Sudbury, Ont. Là, on filma les activités de ces jeunes renards dans leur terrier en juillet et août, et à la chasse en novembre. Les auteurs comparent les comportements de ces renardeaux filmés dans des conditions expérimentales déterminées avec ceux observés dans la nature.

Ils étudient leur élevage, leur taux de croissance, le déroulement de leur mue, leur hiérarchie en matière d'alimentation, les interactions sociales, l'enfouissement de la nourriture, le marquage olfactif, et la succession des activités en hiver et en été. Leurs conclusions préliminaires montrent que la hiérarchie d'alimentation des renardeaux est linéaire et qu'elle est gouvernée par le poids du corps. Il semble que le marquage olfactif soit fortement corrélé avec l'obtention de nourriture plutôt qu'avec sa dissimulation. Les auteurs étudient également le marquage olfactif en fonction de stimulus divers, y compris des enclos inconnus, des formes dressées (chaos de glace), les excréments de congénères et des objets de caractère neutre. Ils étudient les interactions sociales des couples élevant ou non des petits, et leurs conclusions préliminaires indiquent que les comportements changent au cours de la saison de reproduction. Il semble que les changements soient influencés par la photopériode, de même que les mues estivale et hivernale.

Mots-clés: Renard arctique, interactions sociales, *Alopex*.

Introduction

The arctic fox (*Alopex lagopus*) is an abundant predator and furbearer in the arctic tundra biome throughout the circumpolar region (Elton, 1942). Little work has been undertaken to investigate the basic biology of this species. Most of the winter studies on fox have been done using fur harvest

records and carcass examinations. Although many northern communities have reduced their reliance on wildlife resources (Chesemore, 1972), these small furbearers are still of economic importance to people of traditional lifestyles, to tourist outfitters, and to individuals interested in the establishment of northern fox farms. As arctic resource development and tourism increases, knowledge of all species will be essential to reduce the negative impact on a fragile environment. Fox behavioural studies are also important in the understanding of the epidemiology of wildlife diseases and their transmission to man, as arctic fox are attracted to areas of human activity (Eberhardt, 1977; Hason and Eberhardt, 1978).

The main objectives of this study are (1) to establish the husbandry necessary to rear arctic foxes under laboratory conditions, (2) to understand the dynamics of juvenile and adult hierarchies, as they are influenced by changes in age, sex, growth rates and season, and (3) to understand scent marking and visual communications in relation to agonistic interactions and foraging strategies.

Material and methods

In July 1985, six arctic fox kits, three male and three female were live trapped from separate den sites near Eskimo Point, N.W.T., Canada. Temporarily, the kits were housed in individual cages constructed of 2.5 cm mesh rabbit wire (60 cm × 60 cm × 120 cm) and kept inside a garage to reduce human disturbance. Commercial canned dog food (140 gm) was fed twice daily (morning and evening) and water was provided *ad libitum*.

In August, 1985, the foxes were flown in small dog size transport cages, to the Dr. Paul Field Animal Research Facility at Laurentian University, Sudbury, Ontario, where they were divided into two groups. The first group (A) consisted of two males and single female, while the second group (B) was made up of a single male and two females. The two groups of fox were housed in outside pens (4 m × 5 m × 4 m) with cement floors and walls constructed of heavy gauge wire with a 2.5 cm mesh. Pens were isolated from human disturbance by 3 m high walls. Half of the roof was covered with corrugated fiberglass. A metal platform and 20 cm diameter plastic drain pipes were placed within each cage to provide resting places and additional shelter. Pens were hosed out daily during the snow-free months and shovelled weekly during the winter. Each group of animals received 360 gm canned and 2550 gm dry food daily and water was available *ad libitum*. All foxes were vaccinated against rabies, parvoinfluenza and distemper. Deworming required three 1 ml doses of Strongid-T administered at 10 day intervals and an injection of 0.3 ml Dronoit.

In March, 1986, breeding pairs were established in each of the two outside pens and one inside room (4 m × 5 m). Photoperiod inside was kept the same as outside conditions and temperature was held at 15°C. Cement well tiles of 1 m diameter were provided as artifical dens in May, 1986. A hole, 20 cm in diameter was drilled in the side of the tiles to provide an entrance. A wooden lid with a plexiglas viewing window and camera housing allowed observation with minimal disturbance.

Between 12 to 32 weeks of age, groups were monitored daily for the first half hour following feeding. The order in which individuals remained at the dish for 1 min. or longer, as well as the number and outcome of challenges made by other foxes was recorded. The physical appearance of both the attacker and defender was noted. Fox were weighed weekly with a standard spring scale. Statistical treatment of these data is still underway.

Fox were individually placed into an observation room (4 m × 5 m) and monitored for scent marking and visual communications. A fresh peat hummock (1 m × 1 m × 0.5 m) was placed in the room to provide a raised area within the enclosure. A JVC video camera and a Magnivox VCR recorder were used to monitor on a continuous basis. Fox were allowed to adjust to the room for one week. Olfactory communication and scent marking were recorded for all fox. Each day, for five test days, a faecal sample from one of the other foxes was introduced to the room on a metal sheet. On a sixth day a clean sheet was presented as a control. The test animal's reaction was monitored by mapping the spatial distribution of urine and faeces. Types and duration of behaviours were recorded on video tapes. Animals were returned to their pens after two weeks. Tests were carried out on both summer and winter morphs to identify behavioural differences between seasons.

A blind was constructed at a den site in early July, 1985, near Eskimo Point, N.W.T. Behaviours in the wild were recorded on 16 mm film. During November, 1985, film footage of fox foraging near Churchill, Manitoba was also obtained. This film footage and additional video recordings at the den site, will be used to compare behaviours observed in captivity and in the wild.

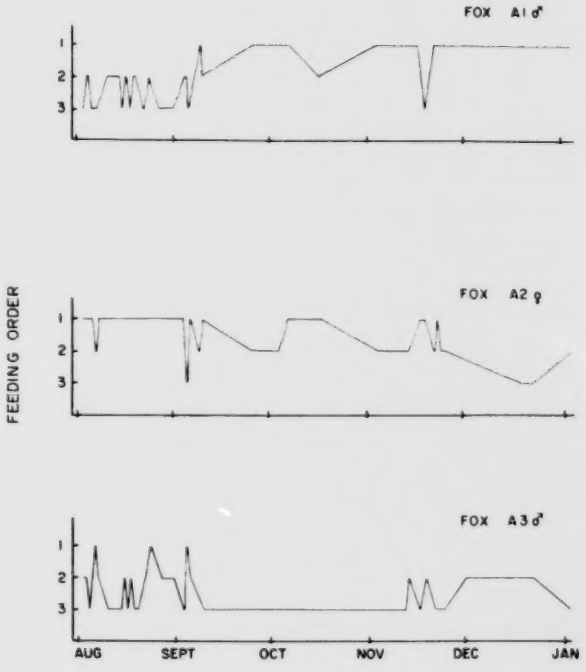


Figure 1. Hierarchial feeding order of group A captive arctic fox kits.

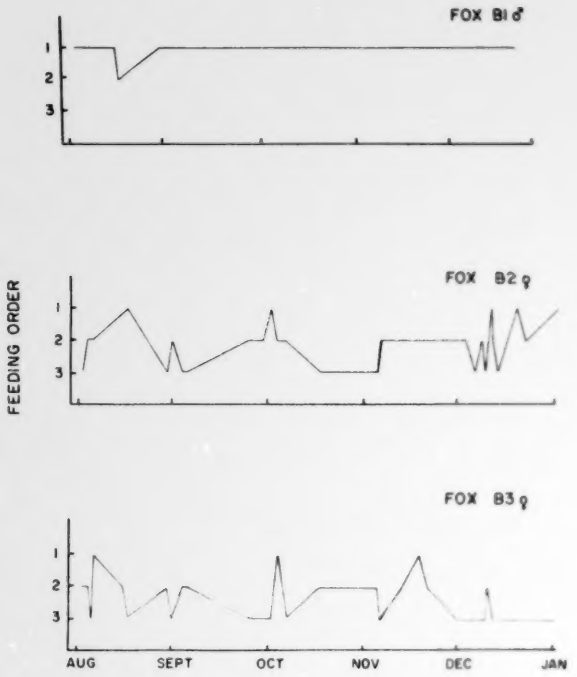


Figure 2. Hierarchial feeding order of group B captive arctic fox kits.

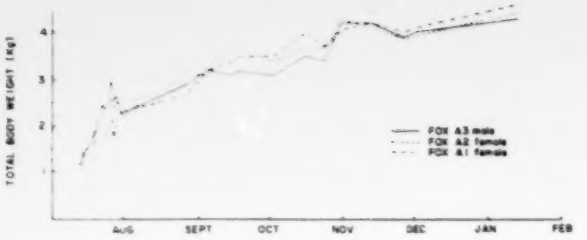


Figure 3. Growth curves for captive arctic fox in group A, from August 1985 to January 1986.

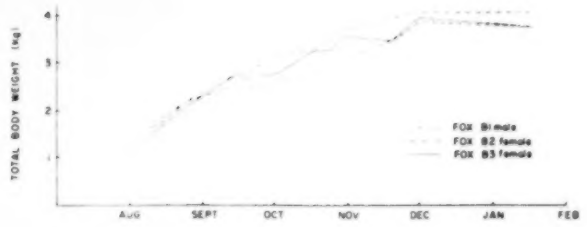


Figure 4. Growth curves for captive arctic fox in group B, from August 1985 to January 1986.

Results

Although all fox appear healthy, no litters were born in 1986. The preliminary data for the kit hierarchies indicate that in both groups feeding hierarchies exist. In group A (Fig. 1) fox A2 ♀ ate first most often until the middle of September at which time fox A1 ♂ became dominant. In group B (Fig. 2) fox B1 ♂ ate first throughout the experiment and occasionally allowed one of the other foxes present to eat with him. The final dominant fox in each group was a male. The dominant rank appears to be relatively stable whereas lower ranks often fluctuate. Weight curves for all fox show the same general trend (Fig. 3 and 4) of initial rapid weight increase and leveling out at approximately 4.2 kg after 25 weeks of age. Dominant males were heaviest in both groups. There appears to be some relationship between weight and hierarchial status. Aggressive interactions ranged from low growls to bites and small fights. Bites were most often delivered to the appendages, back, and neck scruff.

Scent marking preliminary data suggest that fox exhibit micturation behaviour on newly introduced raised structures. Squat urinations are observed most frequently for both males and females. Reactions to conspecifics faeces and new objects include urination and defecation on the introduced sample. Food caching behaviour was observed in both laboratory and field settings. Observations indicate that scent marking occurs in areas where live food is obtained rather than where non-living food is cached.

Discussion

Although no litters were produced by any of the breeding pairs, all animals are in good condition with weights in the range of 4.2 kg. This is above the range of 1.4 kg to 3.2 kg for wild adults (Chesemore, 1975), but similar to a colony maintained in Alaska which had a mean weight of 4.1 kg (Underwood, 1971). Although arctic fox are sexually mature at 9 to 10 months (Banfield, 1977), it has been found that only one third of the vixen at one and a half years of age had placental scars (Macpherson, 1969). This combined with the effects of human disturbances (noise) were believed to explain the lack of litters in 1986.

Dramatic fluctuations in arctic fox populations have been observed throughout their range and have been correlated with small mammal abundance (Elton, 1942; Chitty, 1950; Chesemore, 1967; Macpherson, 1969; Speller, 1972; Garrott, 1980) however, this does not imply a causal relationship. Macpherson concluded that changes in abundance were due primarily to food scarcity which resulted in loss of entire litters and increases in sibling aggression and subsequent mortality. Speller (1972) also attributed decreases in fox reproductive success, in years of food scarcity, to litter reductions caused by aggressive siblings competing for food. Garrott (1980) however, failed to find information to support the theory of litter reduction through sibling aggression. Caley (1972) found that kits were uninhibited when biting littermates and often drew blood, but bites were usually directed towards nonfatal areas such as tails and limbs. Fox (1969) also found bites to be directed towards nonfatal areas such as the shoulder scruff, cheek and muzzle. In this study kit hierarchies were observed. No blood was seen as a result of kit aggression and most bites were to the nonfatal areas mentioned. Although the cranial blows, as described by Macpherson (1969) were not seen, the head was considered

to be the target in most aggressive interactions. When food supplies are low and kits have reduced fitness levels, aggressive interaction as observed in this study, may lead to kit mortality.

Arctic fox are especially territorial during breeding season (Macpherson, 1968; Chesemore, 1975). Eberhardt (1977) found that fox frequently mark protruding objects with either urine or faeces. This same observation has been made in this study, however, further analysis of data is required.

Although Chesmore (1968) found no evidence of caching by arctic fox, this behaviour has been seen to occur (Garrott *et al.*, 1984). In the studies conducted to date caching behaviour has been observed. Neither urination nor defecation seem to be related to this behaviour. Observations indicate that urine marking is associated with the obtainment of live food rather than with the caching of non-living material. This foraging strategy is believed to aid the fox in identifying areas of prey abundance.

Acknowledgments

The authors gratefully acknowledge B. Kovic, J-L. Frund, C. Blomme and P. Dwyer for their technical assistance. Logistic support was provided by the N.W.T. Wildlife Service and the Natural Sciences and Engineering Research Council.

References

Banfield, A.W.F. 1977. The mammals of Canada. Toronto: University of Toronto Press. 43 p.

Caley, M.T. 1972. The ontogeny of predatory behavior in captive arctic fox. Unpubl. M.S. Thesis, University of Alaska, Fairbanks.

Chesemore, D.L. 1967. Ecology of the arctic fox in northern and western Alaska. Unpubl. M.S. Thesis. University of Alaska, Fairbanks.

_____ 1968. Distribution and movements of white foxes in northern and western Alaska. Canadian Journal of Zoology. 46:849–854.

_____ 1975. Ecology of the Arctic fox *Alopex lagopus* in North America: a review. Pages 143–163 *in* M.W. Fox, ed. The wild canids. New York: Van Nostrand Reinhold Co., 580 p.

Chitty, H. 1950. Canadian arctic wildlife enquiry, 1943–49, with summary of results since 1933. Journal of Animal Ecology. 19:180–193.

Eberhardt, L.E., and Hanson W.C. 1978. Long-distance movements of arctic foxes tagged in northern Alaska. Canadian Field Naturalist. 92:386–389.

Eberhardt, W.L. 1977. The biology of arctic and red foxes on the north slope. Unpubl. M.S. Thesis. University of Alaska, Fairbanks.

Elton, C. 1942. Voles, mice and lemmings: problems in population dynamics. Oxford: The Clarendon Press. 496 p.

Fox, M.W. 1969. The anatomy of aggression and its ritualization in Canidae: a developmental and comparative study. Behaviour. 35:242–258.

Garrott, R.A. 1980. Den characteristics, productivity, food habits, and behavior of arctic fox in northern Alaska. Unpubl. M.S. Thesis. Pennsylvania State University.

Garrott, R.A., Eberhardt, L.E., and Hanson, W.C. 1984. Arctic fox denning behaviour in north Alaska. Canadian Journal of Zoology. 62:1636–1640.

Macpherson, A.H. 1969. The dynamics of Canadian arctic fox populations. Wildlife Service, Canadian Department of Indian Affairs and Northern Development, Ottawa. Reprint Series No. 8. 52 p.

Speller, S.W. 1972. Food ecology and hunting behavior of denning arctic fox at Aberdeen Lake, N.W.T. Unpubl. Ph.D. thesis. University of Saskatchewan, Saskatoon.

Underwood, L.S. 1971. The bioenergetics of the arctic fox (*Alopex lagopus* L.). Unpubl. Ph.D. Thesis. Pennsylvania State University.

VEGETATIONAL HISTORY DURING THE LAST 1230 YEARS IN THE BEAR LAKES AREA, AISHIHIK BASIN, YUKON TERRITORY

Xiacheng Wang

Ottawa-Carleton Geoscience Centre,
Department of Geology, University of Ottawa, Ottawa, Ontario K1N 6N5

Level: Ph.D.

Abstract

Pollen diagrams of a 26 cm well preserved peat profile from Bear Lakes, Yukon, area reveal the history of vegetational variation during the last 1230 years. The profile was collected from a small depression between two moraine lobes, and sampled at 1 cm intervals. At the bottom of the profile the occurrence of a key bed, a conspicuous layer of White River Volcanic Ash dated at 1230 Y.B.P., makes it possible to correlate this profile with other studies and facilitate the interpretation of pollen diagrams with its absolute date.

Four local pollen zones can be recognized. Zone 1 represents a forest-shrub-tundra vegetation which occupied the area from at least 1230, Y.B.P. up to approximately 950 Y.B.P. Zone 2 reveals evidence of forest fire around 950 Y.B.P. and a history of reforestation in the area. Zone 3 represents an open spruce forest environment in the area which lasted about 350 years, i.e. from 750 Y.B.P. to 400 Y.B.P. Zone 4 reveals the establishment of close phase spruce forest since about 400 Y.B.P.

Key words: Pollen analysis, late Holocene, Southwestern Yukon

Résumé

Les variations de la couverture végétale dans la région des lacs Bear, Yukon, au cours des 1 230 dernières années, apparaissent à l'examen des diagrammes polliniques établis à partir d'une section pédologique de 26 cm, en bon état, de la tourbe reposant dans une petite dépression entre deux lobes morainiques. L'auteur l'a échantillonnée à 1 cm d'intervalle et a noté la présence d'une couche apparente de cendres volcaniques de White River à la base de la section. Cet horizon-repère datant de -1230 permet la corrélation de

cette section avec celles observées par d'autres chercheurs, et sa datation précise facilite l'interprétation des diagrammes pollinques.

L'auteur a mis en évidence quatre zones polliniques locales: La zone 1 représente une végétation de forêt-arbrisseaux-toundra qui recouvrait la région depuis au moins -1230 jusqu'à environ -950. La zone 2 révèle l'apparition d'incendies de forêt vers cette date, et une régénération forestière ultérieure. La zone 3 représente une milieu de forêt clairsemée d'épinettes ayant duré environ 350 années, c.-à-d. de -750 à -400. Enfin, la zone 4 révèle l'établissement d'une forêt d'épinettes à plein couvert aux environs de -400.

Mots-clés: Analyse pollinique, Holocène récent, Sud-Ouest du Yukon.

Introduction

During the last three summers, field investigations leading to the reconstruction of late Quaternary vegetation and environmental history in the southwest Yukon Territory have been undertaken. This contribution, interpreting one of the pollen profiles collected from the Bear Lakes area (Fig. 1) during the 1986 summer, is a part of this continuing investigation.

Although a number of pollen diagrams have been published from the Yukon Territory and adjacent Alaska and Northwest Territories, few investigations of the past and present vegetation of southwest Yukon Territory have been done, and no published pollen diagrams are available specifically from the Bear Lakes area. The reason for the selection of this site for the investigation is based upon its geographical context. Firstly, this site is a southward extension of my general investigation area in the Aishihik Basin, so the results of pollen analysis may be helpful for the comparison of vegetational variation history latitudinally within the basin. Secondly, this site is at a higher altitude than the other sites of my investigation, so it may give information on the response of vegetation at different altitudes to a variation of environmental conditions. Thirdly, this site has an unusually thick deposit above White River Volcanic Ash which was dated at 1230 years before present (Y.B.P.) (Denton and Karlen, 1977), so it is expected to reveal details of vegetation history during the last 1230 years through a narrow sampling interval. This is the specific purpose of this report.

The Area

The section site is a ca. 800 m depression between two moraine lobes near the Bear Lakes at 61°16′05″N, 137°37′49″W, with an altitude of 1143 m.a.s.l. This area is located within the Aishihik Basin, near its southwest border (Fig. 1).

The glacial history in the area is not known in detail. Ice contact features and linear morainic sediments are widespread. The surrounding topography is a complex of those linear morainic sediments and bedrock, with local relief to about 300 m. Between and surrounding the morainic lobes, organic peat, varying from 10 to 40 cm in depth, occurs, underlain by glacial deposits. The section site is located in one of these small depressions.

The present vegetation in the area is of several different types. Spruce forests occupy the area. The depressions are usually covered by low shrubs and herbs with very sparse spruce trees. A few poplar stands are found at the top of several high morainic lobes. Along with the increase in altitude, the vegetation turns into sparse forest tundra and then tundra.

Climatic data are unavailable directly. There was a climatic station at Aishihik, which is about 40 km north from the site. The records show that there were seven months per year in which the mean daily temperature was below the freezing point. The annual daily mean temperature is 25°F. The extreme of mean total precipitation is 256 mm. So, generally speaking, the study area exhibits a severe continental climate, though it is quite close to the ocean (modern climate summarized from Kendrew and Kerr, 1955).

Methods

The seasonally unfrozen peat deposits were trenched down to the occurrence of permafrost just beneath the White River Volcanic Ash at 26 cm, then collected as a bulk sample using a 38 cm × 5 cm × 4 cm plastic tray. This bulk sample was subsampled at 0.5 cm intervals in the laboratory under frozen conditions using a saw. In total, this 26 cm profile yielded 46 samples, and 25 of them, one of every two samples, were analyzed for palynological purposes.

The laboratory preparation of the samples involves treatment with alkaline and acidic chemicals. The standard preparation and acetolysis procedures (Faegri and Iversen, 1975) were used with minor modifications. Firstly, the samples were boiled with NaOH (10%) for 10 minutes, then a cold treatment with HCL (10%) followed to dissolve carbonates. To remove silicate minerals, a 10 minutes hot treatment with HF (48%) was performed. After that, standard Erdtman acetolysis treatment (9 parts of Acetic Anhydride, 99% in concentration, and 1 part of concentrated Sulfuric Acid) was employed to decompose cellulose and other organic compounds, preceded and followed by treatment with Acetic acid (99.5%). Diluted glycerol (66%) was chosen as the mounting medium.

Pollen identification was aided by about 500 reference slides of pollen collected from southwestern Yukon Territory in the Palynology laboratory of the University of Ottawa. Several well-illustrated publications of pollen taxonomy were referred to when necessary (Bassett *et al.*, 1978; McAndrews *et al.*, 1973; Kapp, 1969; Moore and Webb, 1978). All pollen grains were examined using an Olympus CH microscope with ×200 or ×400 magnification.

Results

Stratigraphy

This 26 cm profile has a very simple stratigraphic sequence. White River Volcanic Ash, a conspicuous layer in sandy facies, occurs from 26 cm to 24.5 cm. Above the Ash layer, it is homogeneous peat deposits, with charcoal in the interval from 19 cm to 16 cm. Beneath the Ash layer, the sediments turn into organic peat again. The permafrost table on July 11 of 1986 occurred at 26 cm.

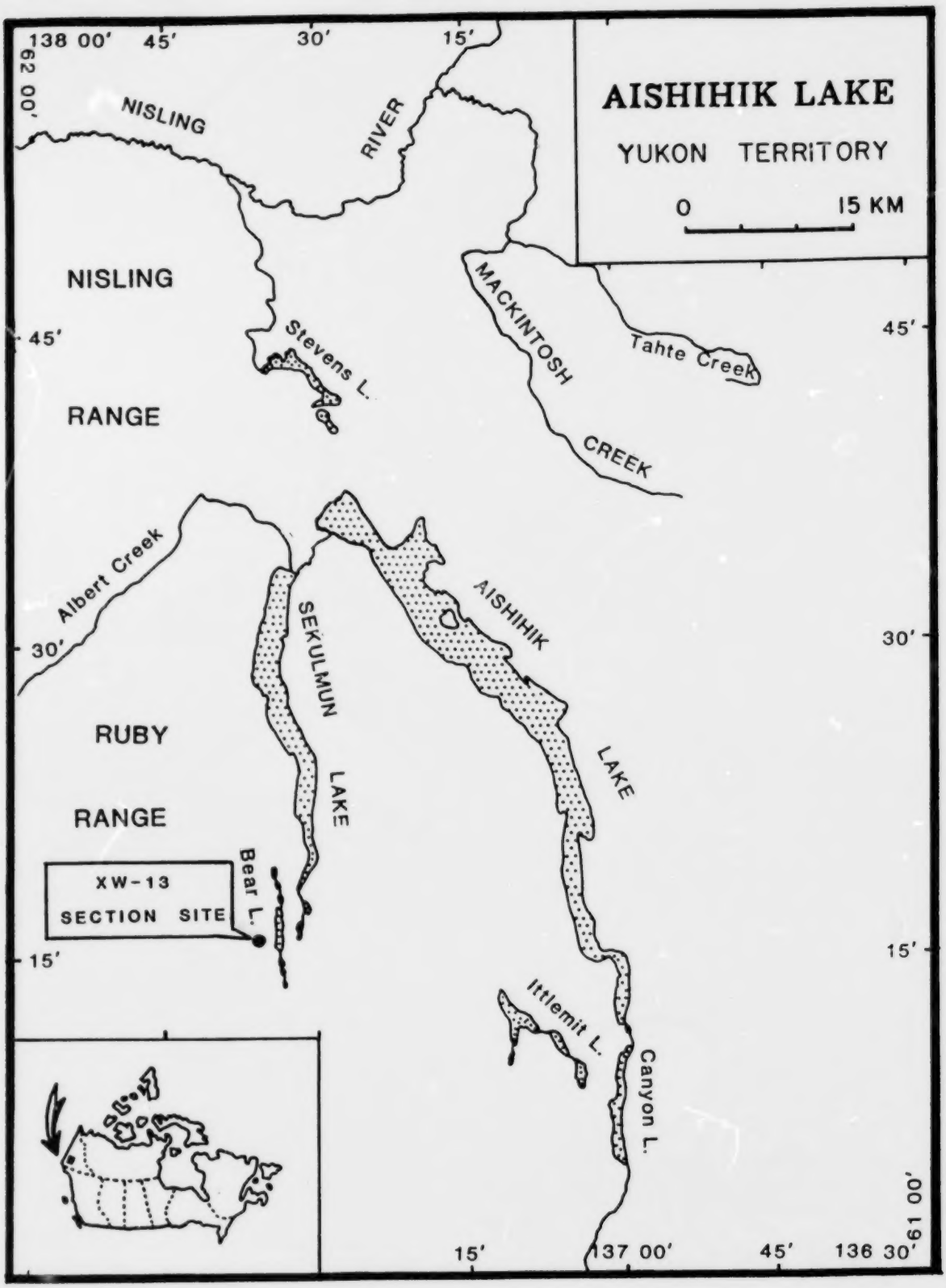


Figure 1. Location map of the general study area within the Aishihik Basin. The Bear Lakes section site is marked as XW-13.

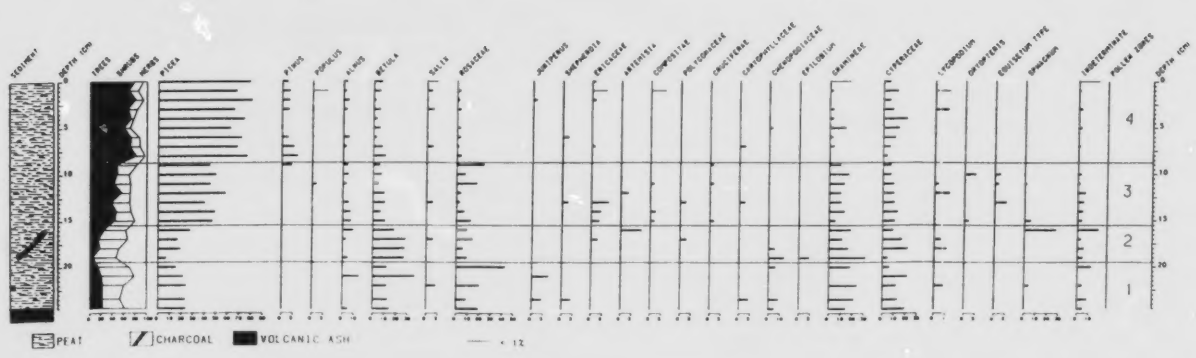


Figure 2. Relative pollen frequency diagram of the profile XW-13 from the Bear Lakes area, showing also the pollen zones.

It is assumed that the surface of the section represents present time, since the site is apparently still a depositional environment. It is also assumed that the sedimentary rate has not obviously changed in this particular depression during the last 1230 years since other absolute dates are not available at present. Under these two assumptions, the chronology of the events can be established tentatively.

Pollen Zones

The results of pollen analysis are presented by a relative pollen frequency diagram (Fig. 2), which is divided into 4 local pollen assemblage zones based upon visual inspection of the variation of pollen spectra. Each of these zones represents a special local event of vegetation development. The White River Volcanic Ash, which was dated at 1230 years before present (Y.B.P.) facilitates the establishment of absolute time sequences under the assumption of a homogeneous sedimentary rate at this site during the last 1230 years.

POLLEN ZONE 1 (24.5 cm TO 19 cm): The sediment of this zone is humified peat. *Picea* varies from 15 to 24%. *Betula* is significant and constantly 12% except one sample which has 35%. Rosaceae has large variations, from 0 to 40%. Other shrub species occur occasionally. In herbaceous species, Cyperaceae and Gramineae have significant and constant values, 14% and 15% on average respectively.

ZONE 2 (19 cm TO 15 cm): This zone is characterized by the macro-charcoal debris in the sediment which is still humified peat. The *Picea* percentage is significantly lower at the base of this zone, down to 7%, and then gradually increases up to 47% at the base of next zone. Shrub species tend to dominate the zone. *Betula*, constantly around 27%, has a significant increase in percentage in comparison with zone 1. Roseaceae varies from 5% to 14%, 9% on average. Herbaceous species are 42% on average, dominated by Gramineae and Cyperaceae. Gramineae is more constant and more abundant, 21% on average. Cyperaceae is more fluctuating than before and varies from 5% to 22%. Chenopodiaceae has a significant occurrence at the lower part of the zone.

ZONE 3 (15 cm TO 8 cm): Zone 3 is dominated by *Picea* pollen. The percentage is constantly around 48%. Shrubs show a conspicuous decrease. The *Betula* percentage is down to 8% on average. *Alnus* is more constant with a low average percentage of 4%. Rosaceae varies from 3% to 23%, 10% on average. Ericaceae is well represented in the lower part of the zone, increased from 3% to 8%. Gramineae and Cyperaceae show an insignificant decrease in this zone.

ZONE 4 (8 cm TO 0 cm): Zone 4 is characterized by an abrupt increase of *Picea* percentage. The average percentage value jumps from 48% in zone 3 to 72%. It is interesting that two small peaks of *Pinus* abundance arise at the bottom and top of the zone, 5% and 3% respectively. In shrub species, *Betula* and Rosaceae have the minimum average values in the profile, 5% and 2% respectively. Herbaceous species also show a decrease in abundance, especially for Gramineae. Cyperaceae, however, shows a much smaller increase than before.

Reconstruction of Paleovegetation

ZONE 1 : -1230 Y.B.P. TO - 950 Y.B.P.

The initial vegetation, following the deposition of the White River Volcanic Ash, was much like a forest-shrub-tundra on the basis of the pollen assemblage. The constant and high *Picea* percentage indicates that spruce trees were present at the site from at least 1230 Y.B.P. to 950 Y.B.P. A log (probably *Picea*) preserved just above the Ash layer can also confirm the interpretation of pollen data. Surficial pollen spectra from the Mackenzie Delta region have shown a relative abundance of about 15 to 25% spruce in the forest-tundra vegetation zone (Ritchie, 1974). Apparently, this result is very similar to the pollen spectra of the Bear Lakes profile and favorable for the above interpretation. As an unlikely alternative, *Picea* pollen could also be due to long distance transportation from other places. MacDonald (1983) has shown that comparable, but much more fluctuating, relative abundance values for *Picea* in the Upper Natala River area may be obtained through long distance transportation of

pollen. This argument, however, is in conflict with the macrofossil evidence. It should be assumed that spruce trees existed in this area during this period.

On the other hand, high abundance of shrub and herbaceous species apparently indicate that these components also played important roles in the vegetation. Rosaceae was often seen in open habitats during the last three field seasons. *Juniperus*, occurring in two of five samples, is also an indicator of open habitats. *Betula* is a very common taxon in the area at present, and its constant values dominate the shrub pollen spectra in this period. Considering all the information mentioned above, the reconstruction of a sparse forest-shrub-tundra vegetation in the area during 1230 to 950 Y.B.P. is appropriate. However, the reason why a forest-shrub-tundra instead of a spruce forest was developed during this period is still unclear. It could be the influence of climatic factors, ecological factors, fires, or a combination of these.

ZONE 2 : - 950 Y.B.P. TO - 750 Y.B.P.

Both pollen data and macrofossils indicate that a fire occurred around 950 Y.B.P. *Picea* has a minimal percentage at the horizon of 950 Y.B.P. which probably reflects that the fire destroyed the spruce trees at the site. The occurrence of *Epilobium* pollen at the same horizon is a good indicator of an open habitat, and this species is often considered as a pioneer after fires (White, 1974). The high percentages of *Betula* and Rosaceae were due to the lack of competition since the fire destroyed the tall stands of spruce and created a favorable habitat for these shrubs. On the other hand, the presence of very well preserved charcoals in the sediments between 19 cm to 15 cm in the profile (referred to 950 to 750 Y.B.P. under the assumption of a homogeneous sedimentary rate) confirms the occurrence of fire. The extent of this fire, however, is not clear from only one profile. The cause of the fire is also unknown at present. Possible causes include natural fire, human impact, etc. The gradual increase of *Picea* percentage from 7% to 47% is a reflection of the reforestation process in the area which took about 200 years to complete. Birks (1980) has shown that, also under the assumption of a constant rate of sediment accumulation, a pioneer phase of herb-dominated assemblages persisted in the Klutlan Glacier area after the White River volcanic eruption for about 200 years, a shrub-tundra phase about 200 years, and the *Picea glauca* forests developed about 800 years ago. This implies that the forestation process took about 400 years to complete in that area, which is much longer than the reforestation process in the Bear Lakes area. However, the reforestation process in the Bear Lakes area was following a fire, and "the importance of post-fire tree regeneration depended on the regeneration potential of the pre-fire communities, . . . and on the timing between a fire occurrence and the onset of cold or mild climatic conditions" (Payette and Gagnon, 1985). It is quite possible for a reforestation process to be complete within 200 years if one of the above mentioned factors was favourable.

ZONE 3 : - 750 Y.B.P. TO - 400 Y.B.P.

High spruce values indicate that an open spruce forest, or at least very dense forest tundra vegetation, existed in the area by about 750 Y.B.P. Spruce pollen abundance is usually proportional to the number of trees growing in the area (Davis and Goodlett, 1960). Comparable spruce values of surficial samples from spruce forests were reported from the Klutlan Glacier (Birks, 1980) and also the Mackenzie Delta area (Ritchie, 1974).

On the other hand, the proportion of shrub and herbaceous species apparently decreases in the pollen diagram. This is probably due to the competition of spruce, its height, longevity, and well-developed root system which enable it to have competitive advantages for light, water, nutrients, etc. It is interesting to note the small peak of Ericaceae at the base of this zone, which could reflect a moist condition in the area during that time.

As an alternative, the vegetation reflected by zone 3 could also be similar to that which occupied the site during the deposition of zone 4. In this case, the pollen production could be retarded for some reason, such as unfavorable climatic condition or ecological factors etc.

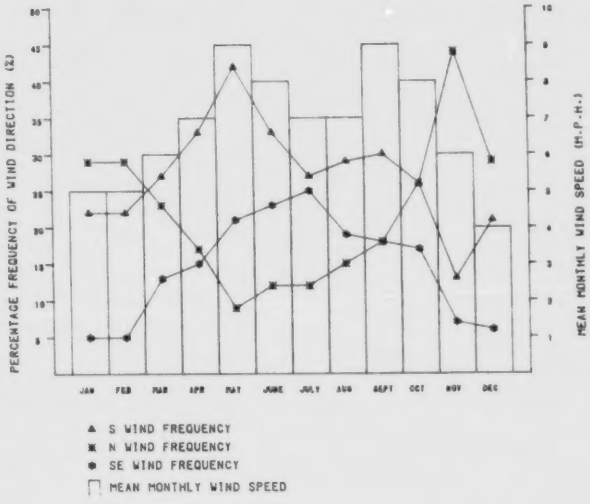


Figure 3. Distribution of the percentage frequencies of wind directions, means of 24 hourly records, 9 years of daily observations, and the histogram of mean monthly wind speed in the Aishihik Lake area (Data collected from Kendrew and Kerr, 1955).

ZONE 4 : - 400 Y.B.P. TO PRESENT

Since about 400 Y.B.P. the vegetation in the area has probably been similar to that at present. The forest is somewhat denser than before. Evidently increased abundance of spruce and decreased values of shrub and herbaceous species reflect this evolution in the vegetation cover.

It is interesting to note that two *Pinus* peaks occur during this period, one from around 150 Y.B.P. to present, and another one from around 450 to 300 Y.B.P., associated with an obvious increase of spruce abundance. The nearest pine trees at present are about 125 km east and 175 km southeast from the Bear Lakes area (Geurts, 1986). The values of these two peaks are very comparable to that in the topmost sample which is assumed to represent present time. Apparently, these two peaks are due to long distance transportation and reflect a change in the atmopsheric circulation system. The analysis of climatic data compiled by Kendrew and Kerr

(1955) from the abandoned Aishihik Climatic Station, which is about 40 km north from the Bear Lakes section site, reveals that the dominant directions of wind are S and SE throughout the year except in winter, which has a dominant direction of north (Fig. 3). On the other hand, the mean monthly wind speeds from spring to fall are higher than those during winter and two maxima occur in May and September (Fig. 3). The pollination period of pine is from May to June (Bassett *et al.*, 1978). In consideration of these factors, it is not difficult to conclude that these two pine peaks are due to long distance transportation from about 175 km away to the southeast. It is absolutely necessary therefore for pollen analysts to consider the influence of wind direction and speed on pollen dispersal, and show great caution in the interpretation of pollen spectra regarding exotic pollen.

Summary and conclusion

In summary, the vegetation covering the Bear Lakes area during the last 1230 Y.B.P. can be divided into four different developing stages, referred to four local pollen zones. From 1230 to 9500 Y.B.P. the site was occupied by forest-shrub-tundra vegetation. Both macrofossil and pollen spectra reflect a forest fire in the area around 950 Y.B.P. The cause of this fire is unclear. This event marks the beginning of the second vegetation development stage. Reforestation in the area took about 200 years to complete. The third stage began around 750 Y.B.P. with a high spruce abundance. It records the history of an open phase spruce forest which occupied the area for about 350 years. A sharp increase of tree pollen, mainly spruce, at 400 Y.B.P. indicates the change of vegetation type in the area and represents the beginning of the last stage. Denser forest, similar to that at present, has probably existed in the site since then. Two concentrated peaks of pine pollen abundance have attracted much attention. These peaks probably reflect the relationship between the pollen dispersal mechanism and the atmospheric circulation system, as well as the relationship between the pollination time and the variation of prevailing wind directions and speeds through time.

Acknowledgments

This study is part of continuing Ph.D. research at the University of Ottawa, and I am thankful for the advice and encouragement of Dr. M.-A. Geurts. Without her guidance and support this study could not have been carried out. I am grateful to Ian Campbell for assistance with sampling in the field as well as revision of the manuscript.

References

Bassett, I.J., Crompton, C.W., and Parmelee, J.A., 1978, An atlas of airborne pollen grains and common fungus spores of Canada, Research Branch, Canada Department of Agriculture, Monograph No. 18, 321 p.

Birks, H.J.B., 1980, Modern pollen assemblages and vegetation history of the moraines of the Klutlan Glacier and its surroundings, Yukon Territory, Canada, Quaternary Research: 14, 101–129.

Davis, M.B., and Goodlett, J.C., 1960, Comparison of the present vegetation with pollen-spectra in surficial samples from Bronington Pond, Vermont. Ecology, vol. 41, No. 2, pp. 346–357.

Denton, G.H., and Karlen, W., 1977, Holocene glacial and tree-line variations in the White River Valley and Skolai Pass, Alaska and Yukon Territory. Quaternary Research, 7, pp. 63–111.

Faegri, K. and Iversen, J., 1975, Textbook of pollen analysis. Munksgaard, 295 p.

Geurts, M.-A., 1986, La palynologie dans les sciences de la terre, Research Notes, Department of Geography, University of Ottawa, Ottawa. 180 p.

Kapp, R.O., 1969, How to know pollen and spores, Wm.C. Brown Company publishers, 249 p.

Kendrew, W.G. and Kerr, D., 1955, The climate of British Columbia and the Yukon Territory. Ottawa, Queens Printer, 222 p.

MacDonald, G.M., 1983, Holocene vegetation history of the Upper Natla River area, Northwest Territories, Canada. Arctic and Alpine Research, Vol. 15, No. 2, pp. 169–180.

McAndrews, J.H., Berti, A.A., and Norris, G. 1973, Key to the Quaternary pollen and spores of the Great Lakes region, Life Sciences Miscellaneous Publication, Royal Ontario Museum, 61 p.

Moore, P.D., and Webb, J.A., 1978, An illustrated guide to pollen analysis, John Wiley and Sons, New York, 133 p.

Payette, S., and Gagnon, R., 1985, Late Holocene deforestation and tree regeneration in the forest-tundra of Quebec, Nature, Vol. 313, No 14, pp. 372.

Ritchie, J.C., 1974, Modern pollen assemblages near the arctic tree line, Mackenzie Delta region, Northwest Territories. Canadian Journal of Botany, 52:381–396.

White, H.A. (ed.), 1974, The Alaska-Yukon wild flowers guide, Alaska Northwest Publishing Company, 218 p.

C. HUMAN SCIENCES
SCIENCES HUMAINES

PERSONAL NAMES, NUMBERS AND NORTHERN POLICY: INUIT IDENTITY IN CANADA

Valerie Alia

Graduate Program in Social and Political Thought, York University, North York, Ontario M3J 1P3

Level: Ph.D.

Abstract

Changing names can be an act of great consequence to the continuance of a culture. Names are even more central to Inuit culture than to many others. The alteration of Inuit personal names can have serious implications, not only for individual identity but for Inuit survival in a larger sense.

Following is a survey of Inuit naming traditions and a brief history of Inuit identification in the Canadian Arctic. The activities and policies of government, traders, and missionaries, have had important impact on Inuit identification and naming; fieldwork conducted in 1985 on Baffin Island clarifies this. The processes of birth certification, census-taking, numbering and naming are addressed, with a focus on the "disc number" system that was in wide use, and the history, development and current status of Project Surname, now in place for fifteen years.

The paper addresses concerns of Inuit and non-Inuit about the legacy of the various identification procedures and the development of policy, present and future.

Key words: Project surname, disc numbers, Inuit names, policy, Baffin Island.

Résumé

Le changement du nom des personnes peut être un acte aux conséquences cruciales pour la pérennité d'une culture. Ces désignations sont encore plus importantes pour la culture inuit que pour bien d'autres, car la modification des noms individuels des Inuit peut avoir des conséquences sérieuses, non seulement pour la personnalité de l'individu, mais aussi pour la survie de la culture collective.

L'auteure fait un tour d'horizon des traditions onomastiques inuit et une brève récapitulation des méthodes d'identification des Inuit dans l'Arctique. Les activités et lignes de conduite des Administrations, des traitants en fourrures et des missionnaires ont eu d'importantes conséquences en cette matière, et lors de l'attribution d'un nom à l'Autochtone. L'auteure a effectué des recherches sur place à l'île de Baffin, qui lui ont permis d'élucider cette question. Elle décrit le processus d'établissement du certificat de naissance et celui du recensement, et l'attribution d'un numéro et d'un nom, en insistant sur la méthode de la plaque d'identité numérique, autrefois largement utilisée, et sur l'élaboration et les progrès réalisés par le Programme "Nom de famille" mis en oeuvre depuis quinze ans.

L'étude décrit les préoccupations des Inuit et des non-Inuit au sujet des conséquences des diverses méthodes d'attribution des noms et de l'élaboration d'une ligne de conduite pour le présent et l'avenir.

Mots-clés: Programme «Nom de famille», plaque numérique d'identité, noms inuit, ligne de conduite, île de Baffin.

Introduction

Formal rituals are infrequent in Inuit life. Birth is an exception, celebrated not as an event in and of itself, but as a preliminary to naming and establishment of personhood. "L'attribution du nom est un acte qui revêt une grande importance" — both for the individual and the community (Robbe 1981:54). This act is separated from the baptismal act followed in accordance with Christian practice. In traditional society names were so closely connected to mortality and personhood that a child experiencing a difficult birth would be renamed, sometimes several times, until he or she was born. Bernard Irqugaqtuq tells of his own birth:

> Since I did not want to be born, Uquqtuq gave me a name so that I would come out more rapidly. That name is Naai. It didn't have much effect for I still did not make my entrance into the world. Papik, Arnakajak's husband, in turn gave me a name, Kapilruq, and I was born. That is why, since then, I also bear the name Kapilruq. But the name destined for me since my conception was Irqugaqtuq (Irqugaqtuq 1977–78:22–23).

In 1985 a man of about thirty verified the continuation of traditional practice. "Our son was crying all the time the week after he was born". A relative who had died "wanted to enter the child", and after that person's name was given to the child, he stopped crying (Alia 1985). A newborn child was buried unnamed if it died. As in many cultures, an Inuit child was not considered human or alive if it had not received a name. The newly named child becomes the *saunik* or "bone" of "all the persons who have previously possessed the name", and the naming ceremony is delayed if the child shows signs of failing health "or if there is some question as to whether it will be kept or disposed of" (Guemple 1969:469). Balikci claims that among the Netsilik, naming actually had an inhibiting effect on infanticide.

> It was essential that infanticide take place prior to naming, since killing a named child might offend the spirit of the reincarnated person, and so the naming of unborn children in hopes of easing childbirth did restrain mothers from practicing infanticide (Balikci 1970:148–9).

Name equals life. Robbe identifies three components of the Inuit individual: *timeq* (body), *tarneq* (soul) and *aleq* (name, also known in the literature as soul-name) (Robbe 1981:46).

Cultural contact often involves changing of names, especially where one culture is subsumed by another. The history of contact in the Canadian Arctic may be traced from early whaling expeditions to current efforts to develop a policy acceptable to Inuit, territorial authorities, industry, and

Ottawa. The current process of devolution of powers from Ottawa to Yellowknife, and the quest for Nunavut and Denendeh will have obvious impact on the policy process.

"Place names . . . serve as an expression of territoriality and thus underline cultural sovereignty" (Müller-Wille 1984). Personal names mark territory of another kind: they represent both the significance of individuals and the position of a culture which has been generally regarded as peripheral to that of the nation. Brody traces Canada's new presence in the Arctic to the turn of the century, when desire for sovereignty was expressed. By the 1920s the "three southern institutions . . . missionaries, policemen, and traders" were well established. Members of these institutions discovered "Eskimos who were 'in need' — of Christianity, trading posts and enforcement of Canadian law" (Brody 1975:18–19).

Baptismal names

After the arrival of the missionaries, most Inuit took baptismal names, modified by pronunciation problems and idiosyncracies. (For example, the many forms of Mary, which has a letter — "r" — that does not occur in Inuktitut, or the shift from Paul to Paulusi or Elisapee from Elizabeth.) Some alterations rendered the originals almost entirely un-English, and many names are neither English nor Inuktitut or are a fusion of the two. The Pangnirtung surname Dialla is a corruption of Taylor.

Class and gender distinctions that permeate English naming were more problematic than pronunciation, as both names and personal pronouns are genderless in Inuktitut. There are no titles to indicate gender, status or class; as Nancy Anilniliak put it "We call you as you are" (Alia 1985).

Confusion and ambiguity accompanied the arrival of baptismal naming. It is impossible to determine the gender of an individual solely from her/his name, because Christian names have sometimes been applied in traditional fashion, without regard for gender. As well, missionaries were not universally welcomed, nor Christian principles universally observed. Etoangat Atsaiyuk (Alia 1985) recalls the slow progress of Christianity during his youth on Blacklead Island: "There were a lot of people opposing Christianity and wanting to stay with shamanism". Most became at least superficial Christians, but the persistence of distinctly Inuit naming practices, non-legal marriages, and traditional adoption suggests that Christianity was applied selectively.

I have found little indication that the introduction of baptismal names *per se* caused great concern. I would suggest that this is because (a) they did not replace Inuktitut names: Inuit were able to continue traditional naming practices and usage; (b) they were added to an individual's accumulated given names in a manner not inconsistent with Inuit tradition; (c) the new names facilitated communication with non-Inuit who had trouble pronouncing Inuit names. Crowe describes a practice I also observed, which he calls "underground naming", in which traditional names are reserved for private use and do not appear on birth certificates. Robbe (1981) documents several devices used in East Greenland to bridge the cultural gap between traditional and Christian naming.

Fingerprints, disc numbers, census and certification

Missionary naming programs did not solve everyone's problems. Traders, policemen, doctors and others "were stumped by the absence of surnames and either unable or unwilling to learn the distinguishing name" . . . (Roberts 1975:2). Fingerprinting for identification was begun in 1932, but the idea of fingerprinting was offensive to many. While a chairman of the Dominion Lands Boards considered fingerprinting harmless, appropriate and efficient (Roberts 1975:3), a medical officer who admitted the infallibility of fingerprinting for identification found it "hardly adaptable . . . to the north" (Bildfell, in Roberts 1975). Fingerprinting soon went out of fashion, never having become standard practice.

The next effort involved assigning identification numbers which were inscribed on pressed-fibre discs. The plan was that each Inuk would be given a disc "on the same lines as the Army identity disk and the same insistence that it be worn at all times" (MacKinnon, in Roberts 1975:6). Each number was composed of elements indicating region, district, community and individual; "W" preceded the Western Arctic numbers and "E" those in the Eastern Arctic. A typical number would be "E5-2468".

Disc numbers were in regular use by the time of the 1941 census. The census-taking process itself had its share of inconsistencies and ironies. Census lists were drawn up in terms of an official standard of "Canadian family" without regard for Inuit family structure or tradition. Children who were full family members according to Inuit practice were designated "boarder", "step" or "adopted" by census-takers. Birth certificates gave precise times and locations of births that had never been recorded (or had been recorded differently by missionaries) for people who traveled widely and identified time and place differently. "You can get the year within a year, and the month of the season, but generally they were just made up" (Neill 1985).

"The situation . . . is a real mess . . ." Inuit in a given locality were said to have been born there "even if, as is known, a large percentage of them were not born in the region they inhabit at present . . . we were shown two birth certificates for the same man indicating that he was born in two places quite distant from each other" (G.M.R. 1972:18). In 1985 several people reported problems similar to that of Kudlu Pitseolak, whose old age pension cheques began to arrive long before her older sister's (Alia 1985).

The inaccuracies may have been caused by more than just bureaucratic misperception or carelessness. Inuit tend to consider it inappropriate (and bad luck) to ask someone's age. The very effort of census and certification must have met with surprise, if not resistance, and some of the inaccuracies may reflect what amounts to an avoidance taboo. Certainly, Inuit in the pre-community Arctic (with no knowledge of future government benefits) would have little motive for facilitating the accuracy of census-taking.

Project surname

In the early 1950s government "moved north in a big way" and fixed settlements, "each an administrative centre", replaced hunting camps as primary places of residence

(Roberts 1975:25). The relocation of Inuit from Northern Quebec to Ellesmere Island occurred during this period. Debate continues today over the extent of voluntariness of these relocations and the extent of government responsibility for the Inuit involved.

During the late 1950s and 1960s government became increasingly sensitive to public opinion. For many, the wearing of numbered discs continued to conjure up images of dog-tagged armies and it was felt that names, whatever their cultural origins, conveyed more humanity and individuality. Concern for human rights was a major '60s theme. "It was an era of people who didn't want to be put into pigeonholes" (Tolley-in Alia 1985), and an era of "rising expectations" (Crowe 1984). Individual identity was a major sub-theme, and creative self-renaming was the order of the day for southern North Americans. In this climate Project Surname was conceived, dedicated to rebirthing Inuit individuals in the name of personal freedom.

"It ended up creating a situation which is just horrendous" says Tolley (Alia 1985). He attributes the problems less to the mood of the 1960s than to the southerners who continued to see the North as "a warehouse: you go in and you get out".

In 1968 the Registrar-General of Vital Statistics was directed to devise a program to eliminate disc numbering as a means of identifying Inuit. Apart from the goal of humanizing identification, Project Surname "would also eliminate a matter which was becoming a rather serious problem" for the Vital Statistics department in the Northwest Territories. This was the issue of "what is an Eskimo, and which newborn infants should be issued discs, and given numbers? . . . where the child resulted from mixed parents, who was an 'Eskimo', and who not? . . . the Indian Act specifically outlines Indian identification, band affiliation and specific entitlements. No such legislation or policy identification exists for the Eskimo population" (Government of the Northwest Territories 1971).

The program designed to replace disc-number identification with southern-style surnames was given the title "Project Surname". In July 1969 Territorial Commissioner Stuart Hodgson appointed Abraham Okpik to carry out the Project. Okpik began on September 23, 1968, and his work was designated an official Centennial program. Legal aids were put into place to assist the process: the courts approved names for a community at a time instead of for each individual, as the Change of Name Ordinance normally required. Birth registration documents were altered individually to reflect the changes.

Although project Surname was never institutionalized as law, the name changes themselves were introduced into the legal process and the individuals affected were renamed under Canadian law. In effect, Inuit lost their traditional identities, sometimes overnight. Children were renamed while they were asleep or away at school. Wives were renamed when their husbands were out hunting. Okpik's task was complicated by the fact that he came from Aklavik in the western Arctic, where the syllabic writing system is not in use and the central and eastern dialects are unfamiliar. Kudlu Pitseolak recalls the procedure in Pangnirtung. Her husband "left town along with some of the other hunters". When he returned "he called 'Hey, guess what? I just got a last name!'" Pitseolak was his father's name. Kudlu was confused by the sudden break with tradition; namesakes were deceased, yet she was being given the name of her still-living husband, who in turn had received his father's given name as a surname. She objected both to the breach of tradition and to the lack of involvement of the women. "Because Abe Okpik was a man, he worked with the men" (Alia 1985).

Okpik recalls "a few retaliations", especially from students and teachers at the Churchill, Manitoba high school where many Inuit were sent. "Eskimo Point and Baker Lake were more trouble" and "one man refused to have his name changed" (Okpik 1985). Today people speak of Project Surname as if it had been a great storm. It "came through"; it "swept away" it "left in its wake . . ." Almost as soon as Project Surname was completed, a government report implied that all was not ideal. It declared that "success in the social sense" could not be assessed "for some years to come" and reported that "already some conflict with the concept of Project Surname has become evident". It admitted that "mistakes have been made", not all of them correctible (Government of the Northwest Territories 1970:15).

Recent developments

Robbe (1981:48) describes extensive genealogical research in Greenland, and a number of people have stressed the importance of initiating similar projects in the Canadian Arctic. Nancy Anilniliak in Pangnirtung and Elise Attagutaluk in Igloolik, began to collect family trees for their communities in the 1980s. Elise Attagutaluk also drafted a resolution, passed by the Inuit Women's Association in 1985, asking that the federal and territorial governments cover the cost of correcting Inuit names that were added or altered during Project Surname. (The present cost of $15 per person for a legal name change is prohibitive for some families, especially large ones.) R.C.M.P. officer Richard Hobson supports the resolution's principle that governement should make the corrections and underwrite the fees: "The mandate should come from Health and Welfare Canada; why should the family pay the cost of correcting an agency mistake?" (Alia 1985).

For Neill, Project Surname "meant an ending to the cultural orientation of the name. The thing that concerns me is it's another corner knocked off the culture, and how many corners can you knock off before it becomes another culture?" (Neill 1984).

Name laws and policies: lessons from Greenland

Contemporary naming policies in Greenland offer a useful view of the balance of power among various authorities, as well as a basis for speculation about the relative importance of personal and place names in determining power relations. Carl Christian Olsen of the Greenland Language Commission explained the naming policies that have emerged from what he terms "Greenland's cultural crisis" (Olsen 1985). In the midst of the gradual move toward home rule, naming powers remain split between Denmark and Greenland. Greenland now controls decisions concerning place names. Family names (surnames) are supervised by the Danish Minister of Justice and personal names by the Danish Minister of Church.

To date, no action has been taken on a request for government to change personal names of Canadian Inuit, but action has begun regarding Inuit (and more generally, native) place names. In May 1986 government naming officials met in Ottawa with native representatives to discuss priorities and plans to clarify and strengthen the presence of native Canadians on the map. Thus, as in Greenland, action regarding place names has preceded action on personal names. Apparently, government is less reluctant (or more willing) to relinquish power and/or affirm native self-determination where the names of places are concerned.

Conclusion

Policies for renaming or re-identifying Inuit have not progressed from chaos to order. While genuine concerns and good will have gone into the formulating of some programs and policies, ethnocentric bias, underfunding and haste have caused a number of problems. There is a need for an extensive and honourable effort to re-evaluate and reformulate policy.

The naming and renaming of individuals is inseparable from other aspects of power and control. Personal names are not metaphors or symbols for larger-scale power; they are key expressions of who rules and how. Inuit sovereignty predates Canada's northern sovereignty by centuries. Naming policies should reflect the historical rights of Canadian Inuit and the diversity of northern peoples, rather than imposing a fictional unity that will ultimately divide more than unite those peoples.

Acknowledgments

Thanks are due: T. Michael Neill, who suggested Project Surname as a case study in politics of naming; Gail Valaskakis, Ludger Müller-Wille, J. Maniapik, Nancy Anilniliak, Jack Hicks, Richard Hobson, Chuck Tolley, Allan Angmarlik, Abe Okpik, Bernadette Immaroitok, Gunther Abramson, Keith Crowe, Helen Kerfoot, Robert Pilot, William Taylor, Lynda Skean Chambers, Meeka Wilson, Arthur Osborne, the Pangnirtung Hamlet Council, and Elise Attagutaluk, who was tragically killed not long after our October 1985 meeting. Her kindness, intelligence, and commitment to improving life for others in the Arctic should be remembered; more than anyone I have met, she understood the importance of maintaining the integrity of personal names.

Research for this project was made possible by a very generous American Fellowship, from the American Association of University Women Educational Foundation, and by grants from York University.

References

Alia, V. 1985-1986. Interviews conducted August and September, Frobisher Bay and Pangnirtung, Baffin Island, Northwest Territories. Andrew Dialla was interpreter.

Balikci, A. 1970. The Netsilik Eskimo. Garden City, New York: The Natural History Press.

Bildfell, Dr. J.A. date unknown. Medical Report, Eastern Arctic Expedition, in Roberts, op. cit.

Briggs, J. 1982. Living Dangerously: the contradictory foundations of value in Canadian Inuit society. In E. Leacock and R. Lee, Politics and History in Band Societies. Cambridge: Cambridge University Press.

_____ 1979. The creation of value in Canadian Inuit society. International Social Science Journal, Vol. 31, No. 3.

_____ 1970. Never in Anger: Portrait of an Eskimo Family. Cambridge: Harvard University Press.

Brody, H. 1975. The People's Land: Eskimos and whites in the eastern Arctic. Middlesex, England: Penguin.

Chairman, Dominion Lands Boards. 1933. Letter to H.H. Rowatt, Deputy Minister, Department of the Interior, June 26, in Roberts, op. cit.:3.

Crowe, K. 1984. Personal communication, Ottawa.

G.M.R. (editor). 1972. The New Eskimo Names; A Real Mess. Eskimo. New Series, No. 3. Spring-Summer:18.

Government of the Northwest Territories. 1971. Project Surname: a summary. (unpublished manuscript). November. Yellowknife.

Guemple, L. 1979. Inuit Socialization: a study of children as social actors in an Eskimo community. In K. Ishwaran (ed.) Childhood and Adolescence in Canada. Toronto: McGraw-Hill Ryerson.

_____ 1969. The Eskimo ritual sponsor: a problem in the fusion of semantic domains. Ethnology, Vol. 8, No. 4. October.

_____ 1965. Saunik: name sharing as a factor governing Eskimo kinship terms. Ethnology, Vol. 4, No. 3. July.

Inuit Women's Association (E. Attagutaluk). 1985. Resolution #85-15. January. Ottawa.

Irqugaqtuq, B. 1977-78. The autobiography of a Pelly Bay Eskimo. Eskimo. Fall-Winter:22-23.

MacKinnon, A.G. (medical officer). 1935. Letter to J. Lorne Turner. In Roberts, op. cit.:15. December 2.

Müller-Wille, L. 1984. The nameless Arctic: Inuit put their names on the map. The Northern Raven, Vol. 4, No. 2 (new series). Autumn. Neill, T.M. 1985. Interviewed by V. Alia. Toronto. January 7.

Okpik, A. 1985. Project Surname. Interviewed by V. Alia. Frobisher Bay. August.

_____ 1970. Project Surname. Territorial Secretary. Northwest Territories Centennial. Yellowknife.

Olsen, C.C. 1985. Discussion with V. Alia during symposium on indigenous place names of the North. Montreal: McGill University. March.

Robbe, P. 1981. Les Noms de personne chez les Amassalimiut. Etudes/Inuit/Studies. Vol. 5, No. 1:45-82.

Roberts, A.B. 1975. Eskimo identification and disc numbers: a brief history. Paper prepared for the Social Development Division, Department of Indian and Northern Affairs, Canada. June.

THE NORTHERN HERITAGE SOCIETY

Notes for a presentation by Madeline d'Argencourt and Debbie Webster

Merivale High School, Ottawa, Ontario K2G 1E2

Abstract

The Northern Heritage Society (N.H.S.) is a non-profit organization, founded in 1979, with its head office based in Yellowknife, N.W.T. The Society's main objective, the Northern Heritage Research Project (N.H.R.P.), emphasizes the research of Inuit culture and pre-history. This is established by the operation of a scientific field school, currently located at Truelove Lowland, on Devon Island in the High Arctic.

This field school teaches young northerners between the ages of seventeen to twenty-two, the skills of scientific research through data collection methods in archaeology, ecology, and environmental geography.

Upon the successful completion of the Northern Heritage Society's field school, the students may find employment in the scientific community. This is done with the help of the

Arctic Science Assistant Program (A.S.A.P.), a job placement project, established by the Society in 1985.

As former field school participants, we feel this program will have a great influence on native students who go through this program and are undecided about furthering their education, or the field of work they might like to work in.

Key words: Yellowknife, N.W.T., Inuit, Truelove Lowland, Devon Island, High Arctic, archaeology, ecology.

Résumé

La Northern Heritage Society (N.H.S., ou «Société du patrimoine culturel nordique") est un organisme à but non lucratif fondé en 1979, et dont le siège social se trouve à Yellowknife, T. N.-O. La principale activité de la Société, le Northern Heritage Research Project (N.H.R.P., ou Programme de recherches sur le patrimoine culturel nordique) porte sur la culture et la préhistoire des Inuit. Ce Programme est mis en oeuvre par une École pratique de formation scientifique installée actuellement à Truelove Lowland, à l'île Devon dans l'Extrême-Arctique.

Cette école pratique enseigne les techniques de la recherche scientifique à de jeunes Nord-Canadiens de 17 à 22 ans, soit les méthodes de recueil des données en archéologie, écologie et géographie de l'environnement.

Après avoir suivi avec succès les cours de l'École pratique, les étudiants peuvent obtenir un emploi dans le secteur scientifique. C'est à ce propos que le programme de placement (Arctic Science Assistant Program, A.S.A.P.), créé par la Société en 1985, peut intervenir.

En tant qu'anciennes participantes aux cours de l'École pratique, les auteurs estiment que son Programme aura beaucoup de succès auprès des étudiants autochtones qui sont incertains au sujet des orientations à prendre pour compléter leur formation, ou des domaines où ils aimeraient oeuvrer.

Mots-clés: Yellowknife, T. N.-O., Inuit, Truelove Lowland, île Devon, Extrême-Arctique, archéologie, écologie.

Introduction

The Northern Heritage Society, commonly referred to as the N.H.S., is an organization that researches Inuit pre-history and culture through archaeology with the help of young northerners. It also deals in northern environmental studies.

N.H.S. is a non-profit organization which was founded in 1979 by; Ellen Bielawski, Sally Cole, Benjamin Hubert, Robert Janes, and Paul Parker (current President). The head office is located in Yellowknife, Northwest Territories. The address is Box 475, Yellowknife, N.W.T., X1A 2N4 (403-873-6582).

The Northern Heritage Research Project

One of the main objectives of the N.H.S. is to preserve and promote northern cultural and natural heritage through research, education and training. This is accomplished by the Northern Heritage Research Project (N.H.R.P.), a scientific research and field training programme for young native northerners. After many months of planning, participants attend a scientific field school in July and August located at Truelove Lowland on Devon Island in the High Arctic.

Funding

As the Northern Heritage Society is a non-profit organization, donations are essential for the continuation of the programme. The main contributors are foundations, corporations, institutes and the Federal and Territorial governments. Due to lack of funding only four students were able to participate in the 1986 field school.

Requirements of participants

Over fifty-five students have participated in the programme since its inception. Participants are Inuit, Metis, Dene, and Caucasian, coming from small communities in the Northwest Territories. Applicants must be between seventeen to twenty-two years of age.

The field school teaches students the skills of scientific research by data collection methods in the areas of archaeology, ecology, and environmental geography. These techniques are intended to equip students with a general scientific knowledge of their heritage.

History and locations

The research project and field school have functioned on Somerset and Devon Islands in the Eastern Arctic for the past eight summers. They are innovative in the sense that they integrate scientific research in the North with a field training programme for residents of the Northwest Territories. Participants work as archaeological and biological field assistants with professional scientists and learn the basic skills of scientific data collection through daily work on field crews. During evening classes at the field camp, they learn the theories and concepts upon which the work is based. These skills, once learned, can be applied in a variety of studies and disciplines and extrapolated to other educational and employment endeavours presently available in Canada's north.

The archaeological programme

The archaeological programme of the Northern Heritage Research Project began operation at Stanwell Fletcher Lake on Somerset Island, Northwest Territories, in 1979, under the direction of Dr. Ellen Bielawski and Sally Cole. Upon completion of the research of a large inland Palaeoeskimo site in 1983, the Northern Cultural Heritage Project, as it was then known under the direction of Margaret Bertulli, moved to Truelove Lowland, Devon Island, in 1984 to begin excavation of a coastal Palaeoeskimo site. In 1985 the archaeology programme of the Northern Heritage Research Project, returned to this site, QkHn-12, to continue excavations begun the previous year.

The geographical programme

In the summer of 1985, a physical and environmental geography curriculum was established. The geography programme operated closely with the arctic ecology programme, with activities often overlapping over space and time.

Students are exposed to most aspects of geographical sciences which consist of climatology, geology, pedology and geomorphology.

The importance of geographical concerns in Northern Canada today is clearly reflected in the numbers of earth scientists from universities, governmental bodies and private corporations carrying out research throughout the Arctic Islands.

Weather study

Students are taught how to record and broadcast the weather. This information is radioed to the Polar Continental Shelf Project (P.C.S.P.) in Resolute Bay at twelve hour intervals (7am and 7pm) each day. The data are important to aviation safety in the region as well as for long-term climatological studies being carried out in Ottawa. Both the documentation and the broadcasting of weather data on the radio are valuable skills to those interested in seeking jobs in Arctic field camps.

Daily curriculum

The programme is a rigorous one with both practical and academic constituents. For one month in the summer, participants work and study ten to twelve hours a day, six days a week. Students are required to attend to a daily routine as follows;

6:00	Cook rises
7:00	Staff rises
7:30	Student wake-up call
7:30–8:15	Breakfast and preparation for day's activities
8:15–9:00	Archaeological crew walks to site
8:30	Biology/Geography crew begins work
9:00–10:30	Work
10:30–10:45	Break
10:45–12:00	Work
12:00–1:00	Lunch, chores crew on duty
1:00–2:30	Work
2:30–2:45	Break
2:45–4:00 or 4:30	Work
4:30–5:00	Archaeological crew returns to camp
5:00–6:00	Check field notes, prepare assignments, free time
6:00–7:00	Supper, chores crew on duty
7:00–7:30	Free time
7:30–9:00	Classes in Lab
9:00	Free time, sauna every fourth night, camp chores

Arctic science assistant programme

Upon successful completion of the N.H.S.'s field school, the students may find employment in the scientific community with the aid of the Arctic Science Assistant Programme (A.S.A.P.). The A.S.A.P. was founded in 1985 by the Northern Heritage Society and assists graduates in job placement.

The A.S.A.P. is designed to achieve two objectives. The first is to help N.H.S. graduates find employment with scientific groups and projects operating in the Northwest Territories. The second is to inform those researchers and agencies about the growing number of young Northerners experienced and interested in working with scientific field parties. As research and development increase in the Northwest Territories, it is important that as many trained Northerners as possible are provided with the opportunity to participate in such expansion.

Conclusion

The Northern Heritage Society helped us understand the diverse cultures of the Arctic and the importance behind research in various scientific fields. The training helped us broaden our minds, taught us how to work independently and provided us with career goals. The interest, enthusiasm and dedication of the instructors is catching and the students participating in the programme have that for the rest of their lives. Graduates set a good example for other interested native youth who wish to become academically involved in their own heritage. We are proud to be graduates.

Further reading

Bielawski, E. 1987. The Northern Heritage Society: a case study in developing science with Northerners. In: Adams, W.P. (ed), Education, Research, Information Systems and the North, ACUNS, Ottawa, 28–31.

Bertulli, M.M. and P. Strahlendorf, 1984. The Northern Heritage Research Project on Truelove Lowland, Devon Island, High Arctic. Annual Report of the NHS, Box 475, Yellowknife, N.W.T.

EIGHTEENTH CENTURY INUIT OCCUPATION OF THE STRAIT OF BELLE ISLE

Reginald Auger

Department of Archaeology, The University of Calgary, Calgary, Alberta T2N 1N4

Level: Ph.D.

Abstract

The study of the Inuit in the Strait of Belle Isle is long overdue. We have in hand a case where there is a profusion of historical documents referring to the encounter between the Natives and Europeans of all origins. The present paper briefly reviews the current interpretation of the historical documents dealing with the Inuit in their southernmost expression and the problems they raise among ethnohistorians. The second part deals with how the author attempts to use archaeological data to refine proposed historical interpretations. The 1983, 1984, and 1986 field seasons in the Strait of Belle Isle reveal Inuit occupations focussing around the European stations. Their closeness to Europeans made the 18th century Inuit abandon their traditional material culture within a short time span.

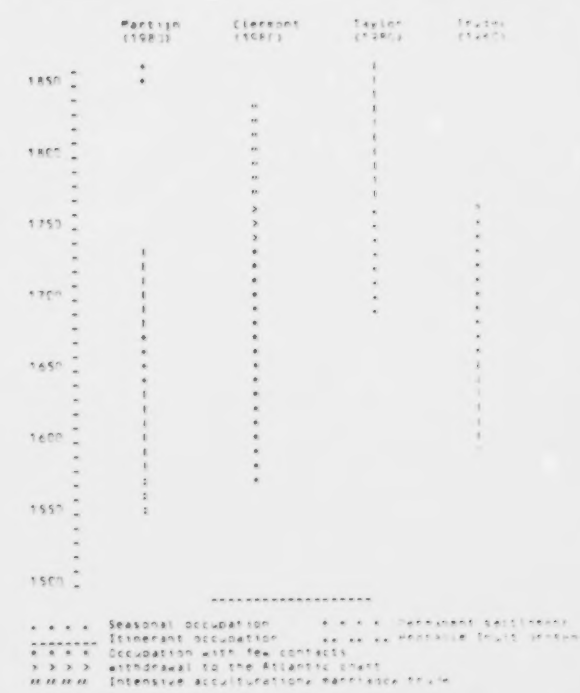
Key words: Labrador, Inuit, Europeans, contacts, 18th century, primary documents, archaeology.

Résumé

Cette recherche sur la présence Inuit dans le détroit de Belle Isle a pour origine le débat soulevé dans Études/Inuit/Studies en 1980. Nous sommes en présence de nombreux documents historiques faisant référence aux rencontres entre Européens et Autochtones. Cet article porte donc dans un premier temps sur une brève revue de l'interprétation des documents historiques relatifs aux Inuit dans leur expression la plus méridionale et des problèmes que les documents soulèvent pour les ethnohistoriens. La deuxième partie illustre la façon dont l'auteur utilise l'archéologie en vue d'approfondir certains problèmes d'interprétation historique. Notons que les recherches poursuivies lors des saisons de fouille de 1983, 1984, et 1986 révèlent une concentration de l'occupation Inuit près des postes européens. La proximité des Inuit aux ressources européennes a fait en sorte que les Inuit du 18ième siècle ont abandonné leur culture matérielle traditionnelle d'une façon très rapide.

Mots-clés: Labrador, Inuit, Européen, contacts, 18ième siècle, documents primaires, archéologie.

TABLE 1
Interpretations of Settlement History in Southern Labrador



Disputes over the history of the Strait of Belle Isle from the 16th to the beginning of the 19th centuries A.D. highlight the contrasts between Martijn (1980a,b,c), Clermont (1980), and J.G. Taylor (1980) (cf. Table 1). The main issues concern the identity of the people whom the first Europeans contacted in the Strait of Belle Isle (Fig. 1), and the timing and nature of that contact. The Europeans were the Basques, French, and British — seasonal and semi-seasonal fishermen.

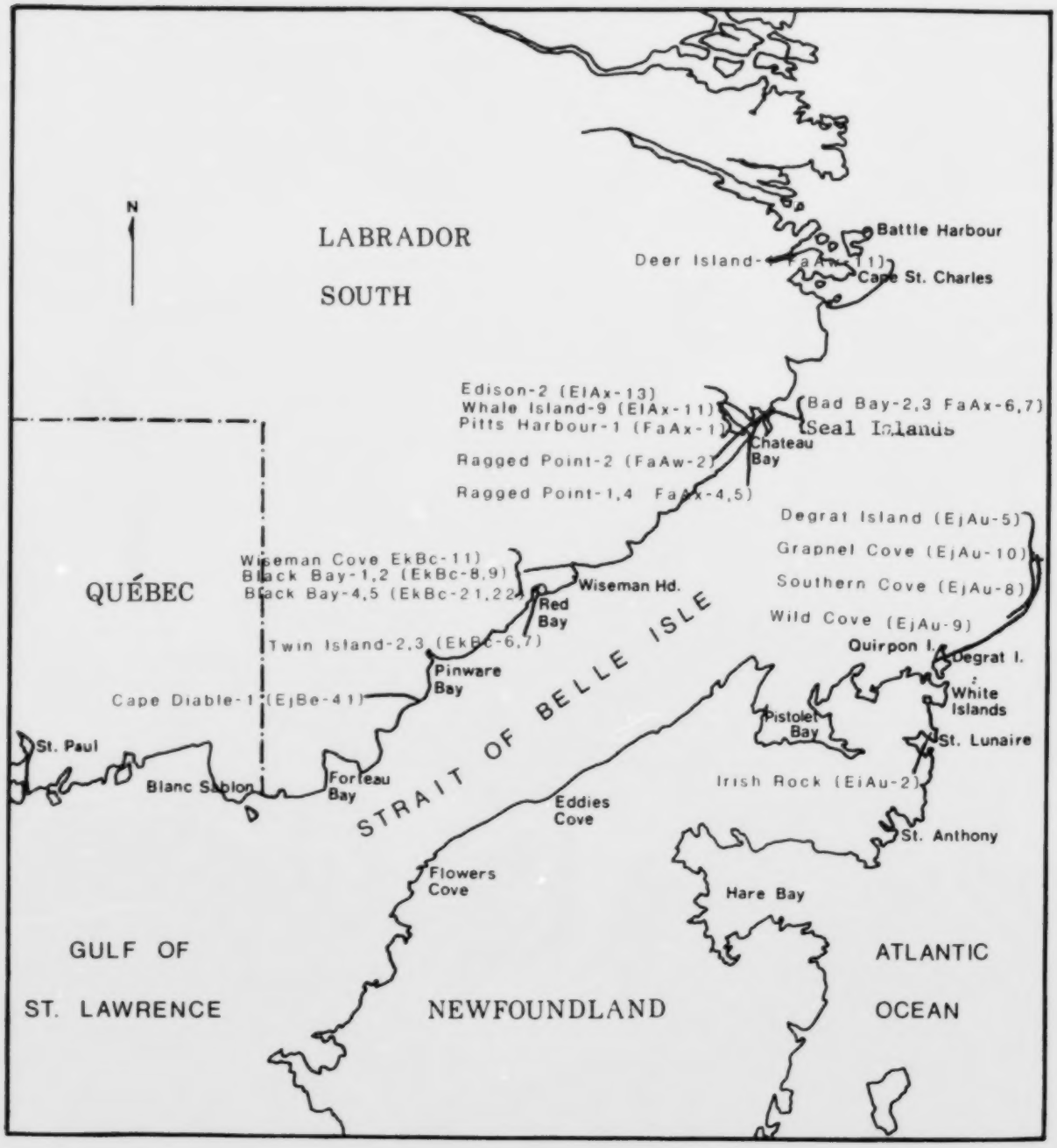
Martijn's (1980a) view, emerging from his thorough map study, is that the "Esquimaux" did not occupy the Quebec-Labrador peninsula before the first half of the 17th century. The only 16th century depiction shows a canoe with five (Thule?) individuals who are shown hunting sea mammals in the Atlantic near the Strait of Belle Isle (Martijn, 1980a:78). Consequently, he suggests that it is only after the abandonment of the area by the Basque whalers and French fishermen, around the early 1620's, that itinerant Inuit bands ventured westward past the Strait of Belle Isle into the Gulf of St. Lawrence. It was the decline of the European fisheries that favored Inuit expansion. Martijn refers to indirect documents to suggest that it was around 1640 that small Inuit groups based around the St. Paul River and Blanc Sablon probably started to establish themselves permanently, farther west along the Cote Nord.

In 1705, with the establishment of Courtemanche's Fort Pontchartain at Brador, the French renewed their attempts to keep the Inuit off the shores west of the Strait of Belle Isle. The last early mention of Inuit on the Cote Nord, that is to say, west of the Strait of Belle Isle, dates from the year 1728, and it is not until the 19th century, when they started working at European-managed fisheries and intermarrying with Europeans, that they reappear in the record.

Clermont's (1980) interpretation is that the Inuit, although not numerous, started to migrate to Southern Labrador, and the Cote Nord as far as Mingan during the period 1550–1660. One purpose of their visits was to scavenge European shipwrecks or plunder the fishermen's shore stations. During the period 1735–1765 the Inuit withdrew from the Cote Nord to the Atlantic Coast, but after 1770, when Cartwright built an establishment at Cape Charles, the Inuit developed friendly relations with Europeans and started to inhabit that area (Clermont 1980:150).

Taylor (1980:188–192) differs drastically from both Martijn and Clermont. He argues that the 16th and 17th century documents do not refer to the Inuit, but rather to Amerindians, most probably to the descendants of the Point Revenge people (cf. Fitzhugh, 1972).

The other area of disagreement concerns the timing of population movements. Taylor (1980:185) categorically denies that the Southern Labrador Inuit population dropped during the period 1735–1765 as Clermont has suggested, and therefore argues against an Inuit population leaving southern Labrador. He sees very few Inuit as actually residing permanently in the region. In contrast with Clermont, Taylor infers that, far from accelerating a withdrawal from the Cote Nord to the Atlantic Coast, it was Cartwright and other European residents who actually attracted more Inuit to the south from northern Labrador in the late 18th and the early 19th centuries. Relying on Jordan and Kaplan's (1980) research in Labrador, Taylor maintains that the Inuit did not move south of the Nain-Okak area until sometime during the 17th century and that Hamilton Inlet may actually have been the southern terminus for their expansion (Taylor, 1980:193).



DISTRIBUTION OF SITES WITH SOD HOUSES

Figure 1. Map of the Strait of Belle Isle including the site distribution.

In opposition to Taylor, Barkham (1980:54–56) developed fairly convincing arguments from her archival research to support the hypothesis that the Basques met the Inuit along the Strait of Belle Isle from the second half of the 16th century, and probably through the 17th century to the beginning of the 18th century. Unlike their contacts with the Montagnais Indians, their contacts with the Inuit were rather hostile.

For the 17th century, Trudel (1981:285–290) has synthesized a wealth of historical documents dealing with the French exploitation of the region. The documents left by Biard, Champlain, Silvy, and Joliet mention that throughout the 17th century there were visitors to the Gulf of St. Lawrence variously referred to as Excommuniqui, Excommunicated, Esquimoes or Savages. Trudel's (1981) studies led him to believe that some Inuit groups occasionally wintered on the Cote Nord. From their base camp, they launched occasional trading expeditions to northern Newfoundland. Trudel mentions also finding information in Joliet's journal that by 1694 the Inuit had left the St. Paul River, although their abandoned encampments could be seen littered with European goods.

According to Martijn's (1980:120) interpretation of the primary documents, by the turn of the 18th century, increased French resistance to Inuit settlement west of Brador slowed down the frequency of Inuit visits west of the Strait of Belle Isle. After the 1760 British conquest and their control of the Strait of Belle Isle, there seems to have been a strong trend initiated by the British to lure the Inuit back to Northern Labrador. Thus, the Moravian missionaries, after an abortive attempt to establish a mission in Labrador in 1752, received British assistance in the 1760's, and established their first mission at Nain in 1771. This first in a series of missions played an important role in attracting the Inuit to settle around the missions (Taylor, 1974).

My own research on the 17th and 18th century primary documents makes me favor the hypothesis that the people met by the Europeans in the Strait of Belle Isle during that time period were Inuit. After this brief review of the historical context, let us see what the archaeological record indicates. In contrast to the study of the historical documents for the area, the archaeological research is in its infancy.

Martijn's (Martijn, 1974; Martijn and Clermont, 1980) survey of the St. Paul River region recovered remains associated with structures located in boulder fields. He interpreted his discovery of a mandible, a snow knife, an arrow shaft, and a metal object as supporting the presence of an Inuit group probably during the 17th century. Moreover, the effort involved in the construction of boulder structures leads Martijn to suggest that the occupation was undoubtedly more permanent than a temporary visit. Nevertheless, based on the evidence available, Taylor (1980) questions Martijn's suggestion of an Inuit presence on the Cote Nord during the second half of the 17th century.

Further evidence to support Martijn's interpretation of an Inuit population on the Cote Nord during the 17th century comes from the work of Dumais (1985) at Baie Des Belles Amours, 20 km to the east of the St. Paul River. The architecture of two semi-subterranean houses with entrance passage sampled by Dumais is comparable to houses excavated by Schledermann (1976) in northern Labrador; hence his argument for a late 17th to early 18th century occupation. The collection from those two houses includes nails, coarse earthenware, window glass, soapstone, and nails modified into projectile points.

The three seasons of fieldwork that I conducted on both shores of the Strait of Belle Isle (Pastore and Auger, 1984; Auger, 1985) failed to identify any occupations dating from the 16th or the 17th centuries. In fact, it revealed Inuit winter settlements at their peak during the second half of the 18th century to the beginning of the 19th century.

The 1983 research in the Red Bay area concentrated on Twin Island and at Black Bay. The limited sampling of Twin Island-3 revealed the presence of a poorly defined whalebone vertebrae tent ring ca. 4.5 m in diameter. The material recovered from that structure included badly corroded wrought iron nails, European flint, and baleen. Tuck (1984; 1985) subsequently continued the excavation at the site and uncovered further evidence of an Inuit presence at Twin Island-3 such as a soapstone pendant, a drill bit, and a ground slate harpoon end blade. Twin Island-2 was more informative than Twin Island-3 in terms of its architecture. A subrectangular structure ca. 4 by 8 m was sampled, it was delineated by peat walls and an entrance way. The material from Twin Island-2 was tentatively interpreted as resulting from temporary hunting or trading Inuit camps.

More work at Black Bay, 10 km to the east of Twin Island allowed us to locate three more houses, and the sampling of a fourth peat walled house at Wiseman's Cove yielded a collection comparable to what we had from Twin Island-2 — wrought iron nails, fluted pipe bowls, ceramics, and other iron objects. The date suggested for that occupation is around the end of the 18th century to the beginning of the 19th century based on the presence of creamware at the site.

As observed after the 1983 season there was still doubt as to whether all the houses discovered had really been occupied by Inuit; as the artifacts recovered were essentially European-made such as creamware ceramics, nails, spikes, glass and kaolin pipes. Therefore, the possibility of a European or a mixed Inuit-European 18th to 19th century population still existed.

Based on the 1983 observations, the 1984 fieldwork aimed at identifying alternative criteria, for a better definition of an Inuit occupation. More especially, we aimed at discovering other houses whose architecture would be similar to Labrador Inuit houses as reported in Kaplan's (1983) dissertation. The second aim was to obtain traditional artifacts that would bring definitive proof of an Inuit presence. Although Kaplan's research in Labrador showed that the Inuit did not have much of their traditional material culture left at that time period, elements like trade beads, soapstone, and harpoon heads would have been considered diagnostic elements (Jordan, pers. comm.). As a result, we set out to survey the south shore of the Strait of Belle Isle in order to understand the distribution of Labrador Inuit houses if any were found, and to excavate one potential Inuit house reported for Degrat Island the previous year (Fitzhugh, 1983).

Prior to excavation, the house at Degrat Island was a rectangular feature delineated by three raised sod walls and a bedrock outcrop, roughly oriented east-west and measuring 7 by 5 m (Fig. 2). Topography was an important factor in

Figure 2. House #2 at Degrat Island

the house location; its length ran parallel to a bedrock outcrop, and a ledge, visible after the excavation, was probably used as a sleeping platform. The floor of the house was a series of flat stones tightly set together to create a pavement. The material used to build the walls was a mixture of sod blocks and rocks. Upon examination of the stratification in a test-pit made previously (Fitzhugh, 1983), it was anticipated that the excavation of the site would reveal a single component. Subsequent work yielded a rather different picture of the site.

Based on the observations made on ceramics and the stratigraphy, two occupations were suggested. Starting with the most obvious, the house occupants left a rectangular sod and stone-walled dwelling flanked against the bedrock outcrop. The artifacts left by the occupants included creamware fragments, 18th century pipes and wrought iron nails lying on the house floor. That occupation rested on the remains of a previous occupation, as evidenced by level III and downward.

In contrast to the recent occupation, the earliest occupation underneath it, as represented by the wood chips in level III, showed an absence of the decorated creamware. Instead, coarse earthenware ceramic was recovered, along with some salt glazed sherds. These were associated with kaolin pipe fragments, which dated back to the first half of the 17th century.

By and large, my preliminary inventory of the two occupations shows that there were occupants who left material dating from the first half of the 17th century and the succeeding 18th century. Pending further laboratory identification, I can conjecture that the early 17th century level, which does not contain any traditional Inuit artifacts, represents a European midden resulting from a fishing shore station. The last occupation represents an Inuit occupation late in the 18th century; at a time when the Inuit were prevented from going farther west than Brador, and started to settle along the Strait of Belle Isle, close to the Atlantic Coast.

The 1986 season warrants the hypothesis of an intensification of Inuit settlements close to the Atlantic shore during the second half of the 18th century. The survey of the north shore of the Strait of Belle Isle suggests a concentration of Inuit settlements probably caused by the establishment of major British stations. Effectively, the concentration of Inuit sites around Chateau Bay (Fig. 1) suggests that the Inuit were probably trading with the British at Fort York, and perhaps working for them as well. The least we can say is that they were attracted to Chateau Bay by the British fishing in that area. The survey of Chateau Bay allowed us to locate eight Inuit sites totaling 12 sod walled houses altogether. Except for one, they are all small sub-rectangular houses approximating ca. 4 by 7 m in size. None of them has any

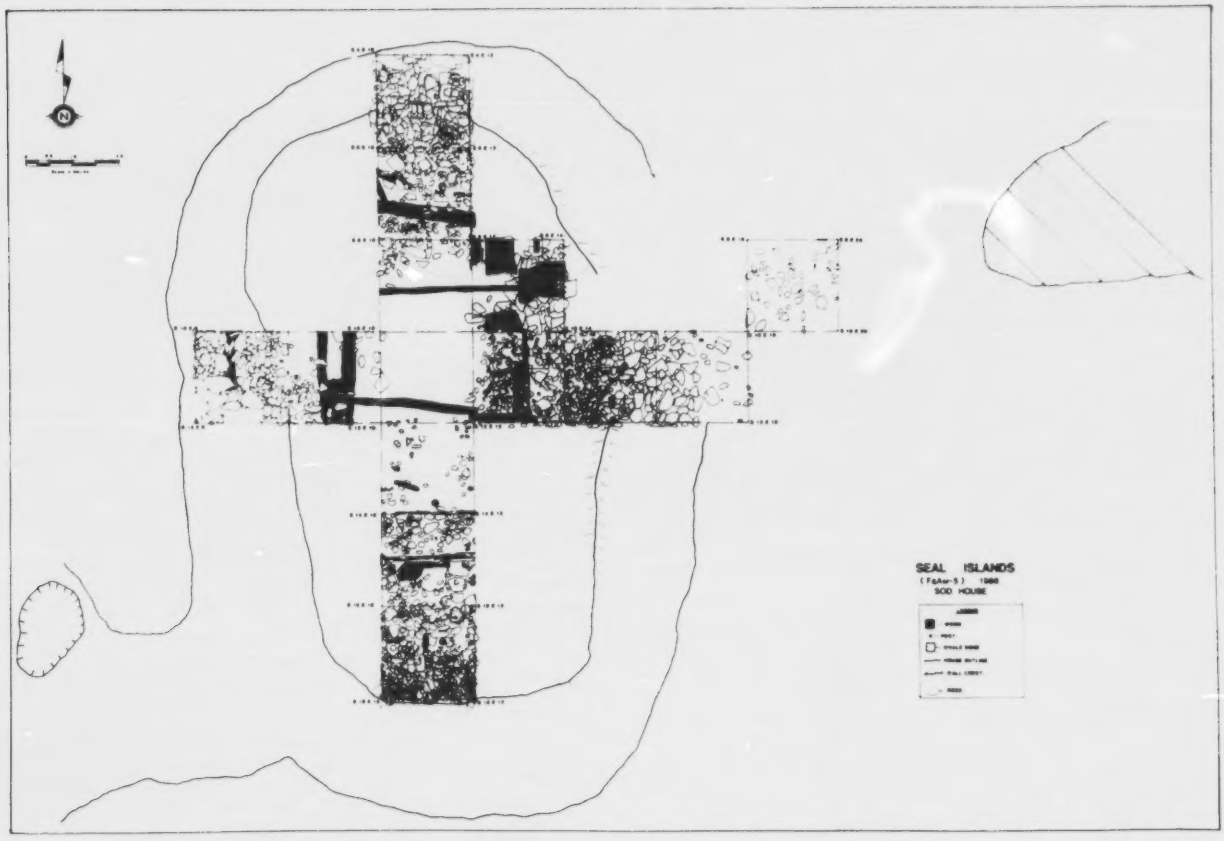


Figure 3. Plan of the Seal Islands house

underground entrance passage but a gap in the walls functioned as the entrance way. They all have a midden in front of them by the entrance. Sampling of eleven houses and the excavation of one of them yielded time diagnostic artifacts such as wrought iron nails and creamware, therefore based on the presence of creamware, a maximum date of 1760 is attributed to them. They probably all correspond to the Inuit encampments plotted on a 1765 British map of Chateau Bay (cf. Lygsaght, 1971:184).

Although thirteen houses were found in Chateau Bay, we concentrated at the excavation of a house located at the Seal Islands (Fig. 3). Prior to the completion of the survey, this house was the nearest to the settlement reported on the 1765 map, and believed to be from Inuit origins. Its location on an isolated island, without access to fresh water, and exposed to storms sweeping the area was suggestive of an Inuit occupation. Finally, preliminary sampling showed unusually good faunal preservation which made the house a good choice for documenting the economy at the site.

The house on Seal Islands is a rectangular dwelling measuring 12 by 6.5 m at the crest of the wall. Its corner entrance opens to the east. The house was originally built on a boulder beach covered with blocks measuring 15–25 cm in size. Prior to the house construction, the people cleared off the beach from surface blocks in order to make a levelled house floor. The same rocks were placed on the walls along with sod blocks containing the artifacts from a previous occupation of the island. The profile of the west wall demonstrates that the walls were originally 1.2 to 1.4 m thick, and approximately 1.5 m high. The building material used in their construction tumbled on both sides after the house was abandoned and created a feature with walls 4 m wide prior to excavation. The poorly preserved remains of a vertical post in the centre of the house suggested that it was probably an "A" frame structue. The traces of floor joists transversing the house suggests that the occupants built a wood floor with planks laid down lengthwise. A raised sleeping platform was built at the rear using flat stones.

There is no evidence of a fireplace but stove parts found close to the surface of the house midden make one think that they probably came from trade between the Inuit and the Europeans. The house typology put forward by Kaplan (1983) for Labrador implies that above ground houses with corner entrance by opposition to semi-subterranean rectangular dwellings would date from the 19th century but I suspect that above ground houses in the Strait of Belle Isle, can date from the 18th century. In fact, it is likely that above ground houses if they effectively resulted from the acquisition of European stoves by the Inuit, as suggested by Kleivan (1966) (Kaplan 1983:250), could very well have been built in the Strait of Belle Isle first.

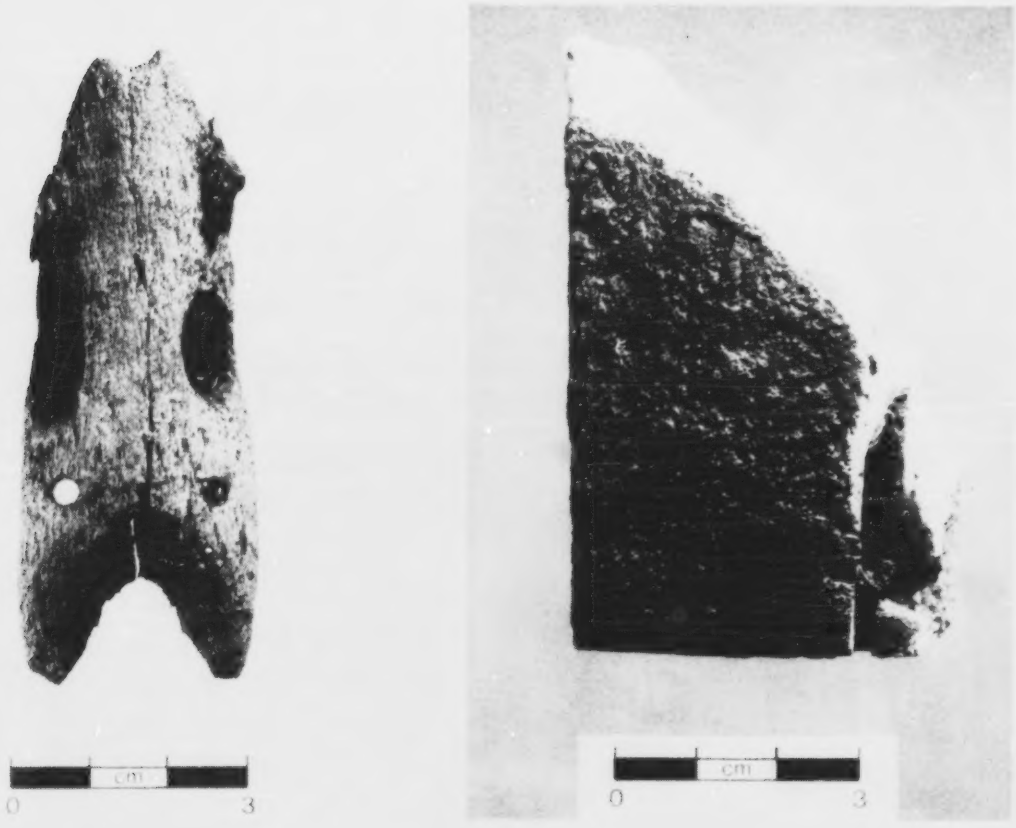


Figure 4. Harpoon and soapstone vessel fragment.

Apart from the hundreds of nails, the collection includes a soapstone vessel fragment mended with iron, a whalebone harpoon with a metal inset (Fig. 4), and a half dozen glass beads. Those three elements are solid evidence of a Labrador Inuit occupation.

Discussion

The time period and the region covered by my research are very restricted; but when I considered the possibility that the Inuit could have been in the Strait of Belle Isle as early as the end of the 16th century, and as far west as Mingan, I decided to concentrate on an even more restricted study on the nature of the exchange between the Inuit and the Europeans.

Prior to the 18th century the Inuit might have chosen to live west of Brador probably because of the attraction of the French presence in the area of Anticosti Island. By the turn of the 18th century, however, the increased pressure for fishing territory forced the French to spread to the east where they established a fort at Brador to protect their fishing installations. Such factors are interpreted as preventing the Inuit from venturing west past Brador.

The question of cultural identity is still only partly resolved. Even though the settlement pattern corresponds to an Inuit type of occupation and the houses are architecturally very similar to Labrador Inuit houses, there are very few traditional Inuit artifacts recovered. Nevertheless, the evidence points to an Inuit presence during the late 18th century. The assemblages compare well to late 18th century artifact inventories at sites located in Labrador (Jordan and Kaplan, 1980), though traditional Inuit manufacture is less apparent. The collections include worked nails and spikes, fishhooks, glass beads, clay pipes, creamware fragments, and most important, a soapstone fragment mended with iron and a whalebone harpoon head with metal inset from the Seal Islands site. Pending further laboratory research, I assume that the paucity of the traditional artifacts during the 18th century results from a greater accessibility to European made goods by the Inuit.

Acknowledgments

Funding for the three seasons of field research was provided by a Memorial University Vice-President's Research Grant, the Institute of Social and Economic Research, Memorial University, the Historic Resources Division, Department of Culture Recreation and Youth, Government of Newfoundland

and Labrador, the Northern Scientific Training Programme of the Department of Indian and Northern Affairs, the Arctic Institute of North America, and The University of Calgary Thesis Research Grant.

I am also thankful to both Dr. J. Scott Raymond and Dr. Richard Forbis from the Department of Archaeology, at The University of Calgary for reading and commenting on a previous version of this paper, nevertheless I remain solely responsible for any shortcomings.

References

Auger, R. 1985. Progress report on Inuit investigations in the Strait of Belle Isle. In: Sproull Thomson, J., and Thomson, C., ed. Archaeology in Newfoundland and Labrador 1984: Annual report #5. St. John's: Newfoundland Museum. 272-293.

Barkham, Selma de L. 1980. A Note on the Strait of Belle Isle during the period of Basque contact with Indians and Inuit. Études/Inuit/Studies. 4(1-2):51-58.

Clermont, N. 1980. Les Inuit du Labrador méridional avant Cartwright. Études/Inuit/Studies. 4(1-2):147-166.

Dumais, P. 1985. Évaluation du site archéologique Inuit EiBi-12, Baie Des Belles Amours, Basse-Côte-Nord. Unpubl. report, Ministère des affaires culturelles, Québec.

Fitzhugh, W.W. 1972. Environmental archaeology and cultural systems in Hamilton inlet, Labrador. Washington D.C.: Smithsonian Institution Press. Contributions to Anthropology, #16.

Fitzhugh, W.W. 1983. Archaeological surveys in the Strait of Belle Isle. In: Sproull Thomson, J., and Thomson, C., ed. Archaeology in Newfoundland and Labrador 1982: Annual report #3. St. John's: Newfoundland Museum. 118-132.

Jordan, R.H., and Kaplan, S.A. 1980. An archaeological view of the Inuit/European contact period in central Labrador. Études/Inuit/Studies. 4(1-2):35-46.

Kaplan, S.A., 1983. Economic and social change in Labrador Neo-Eskimo culture. Unpubl. Ph.D. dissertation, Department of Anthropology, Bryn Mawr College, Pensylvania.

Kleivan, H., 1966. The Eskimos of northeast Labrador: A history of Eskimo-White relations 1171-1955. Norsk Polarinstitutt Skrifter, #139.

Lysaght, A.M., 1971. Joseph Banks in Newfoundland and Labrador, 1766. His diary, manuscripts and collections. London: Faber and Faber. 512 p.

Martijn, C.A., 1974. An archaeological research on the lower St. Lawrence North Shore, Quebec. In: Byrne, W., ed. Archaeological salvage projects 1972. Ottawa: Mercury Series, Archaeological Survey of Canada Paper #15. 112-130.

_____. 1980a. The "Esquimaux" in the 17th and 18th century cartography of the Gulf of St. Lawrence: A preliminary discussion. Études/Inuit/Studies. 4(1-2):77-104.

_____. 1980b. La présence Inuit sur la Côte Nord du golfe St-Laurent a l'époque historique. Études/Inuit/Studies. 4(1-2):105-126.

_____. 1980c. The Inuit of Southern Quebec-Labrador: A rejoinder to J. Garth Taylor. Études/Inuit/Studies. 4(1-2):194-198.

_____ and Clermont, N. 1980 Les structures de pierres et la mandibule du site EiBk-3, Basse-Côte Nord, Québec. Études/Inuit/Studies. 4(1-2):127-134.

Pastore, R.T., and Auger, R. 1984. Archaeological investigations at Red Bay and Black Bay, Labrador. In: Sproull Thomson, J., and Thomson, C., ed. Archaeology in Newfoundland and Labrador 1983: Annual report #4. St. John's: Newfoundland Museum. 55-69.

Schledermann, P. 1976. Thule culture communal houses in Labrador. Arctic 29(1):27-37.

Taylor, J.G. 1980. The Inuit of Southern Quebec-Labrador: Reviewing the evidence. Études/Inuit/Studies. 4(1-2):185-193.

Taylor, J.G. 1974. Labrador Eskimo settlements of the early contact period. Ottawa: National Museums of Canada Publications in ethnology, #9.

Trudel, F. 1981. Inuit, Amerindians and Europeans: A study of interethnic economic relations on the Canadian south-eastern seaboard (1500-1800). Unpubl. Ph.D. dissertation, Department of Anthropology, The University of Connecticut.

Tuck, J.A. 1984. 1983 Excavations at Red Bay, Labrador. In: Sproull Thomson, J., and Thomson, C., ed. Archaeology in Newfoundland and Labrador 1983: Annual report #4. St. John's: Newfoundland Museum. 70-81.

_____ 1985. 1984 Excavations at Red Bay, Labrador. In: Sproull Thomson, J., and Thomson, C., ed. Archaeology in Newfoundland and Labrador 1984: Annual report #5. St. John's: Newfoundland Museum. 224-247.

RELATIONS INTER-ETHNIQUES ET DYNAMIQUE DE DÉVELOPPEMENT EN MILIEU NORDIQUE

Michel Barbeau

Études Régionales, Université du Québec à Chicoutimi, Chicoutimi, Québec G7H 2B1

Niveau: Maîtrise

Résumé

Le programme de maîtrise en études régionales de l'Université du Québec à Chicoutimi a pour objectifs de promouvoir la réflexion théorique et la recherche sur les régions, dans une perspective multidisciplinaire. Plus précisément, le programme permet une réflexion critique sur le concept même de région et ses problèmes de développement, et un approfondissement des connaissances théoriques pertinentes à l'analyse des sociétés régionales.

Dans cette optique, cette communication, qui présente les grandes lignes et les principales conclusions d'un mémoire portant sur «Les relations inter-ethniques et la dynamique de développement en milieu nordique», démontre toute la pertinence de la réflexion «régionale» dans un contexte nordique.

Mots-clés: Relation, blanc, Amerindien, développement, nord autochtone, allochtone, Schefferville.

The M.A. program in regional studies at the University of Québec at Chicoutimi is intended to stimulate theoretical study and research on the subject of regions in a multidisciplinary perspective. More exactly, the program provides the opportunity for critical thinking about the regional concept itself and the problems of regional development and for a more thorough examination of theories relevant to the analysis of regional societies.

Within this framework the paper, which presents the general summary and preliminary conclusions of a thesis on "Inter-ethnic relations and the dynamics of development in a northern environment", shows how relevant the "regional" approach is in a northern context.

Key words: Relationship, white, Amerindian, development, native North, non-native, Schefferville.

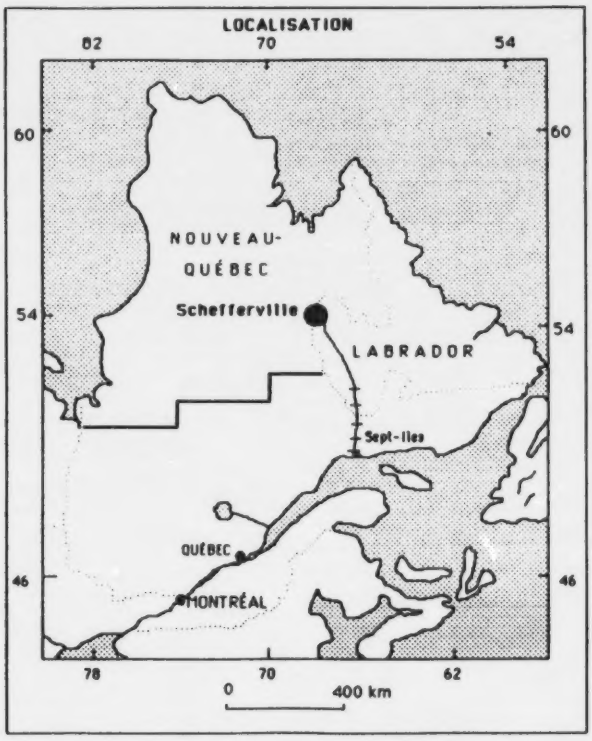


Figure 1. Localisation de Schefferville.

TABLEAU 1
Main-d'oeuvre autochtone par rapport à la main-d'oeuvre totale employée par l'Iron Ore à Schefferville.

	1950-1955	Décennies 1960-1970	1980	2 nov. 1982
Montagnais	10	25-26[2]	25-26[3]	6[4]
Naskapis		20[2]	20[3]	n d
Blancs	6900*	1223	305	161
TOTAL	6900[1]	1268	350	167[5]

* Approximation

Sources:

1. Grégoire, 1976
2. MRC DE CANIAPISCAU 1985. La littérature mentionne pour l'époque qu'environ 1000 employés de l'IOC oeuvraient à Schefferville. DESY rapporte qu'en 1962 «on a atteint (pour les Amérindiens) le chiffre maximum de 80 employés au mois de juillet (111), dès août on commençait à débaucher (sic); dès septembre, il ne restait plus que 30 Indiens; on prévoyait en garder une vingtaine pour l'hiver, des Montagnais en majeure partie» (Désy, 1963:54).
3. Wolfe, 1983.
4. Après la mise à pied de l'automne 1981 (Vakil, A.C. in Bradbury J. et Wolfe J.M., 1983)
5. IOC 1983.

Problématique

La mise en valeur du Nord est synonyme d'exploitation des ressources naturelles de régions isolées et éloignées. C'est aussi synonyme de mal-développement et d'absence de planification inhérent à un modèle de développement régional exogène et extraverti. La désertion du territoire par la compagnie minière Iron Ore en novembre 1983 marque un tournant dans l'histoire régionale de la Côte-Nord: Schefferville, ville nordique à vocation unique typique du Nord, est devenue à son tour, tout comme Gagnon, victime de «l'impermanence» «caractéristique des foyers d'exploitation pionniers» (Hamelin, 1975) et du fameux mythe du Nord, cette «Terre promise» (Morrissonneau, 1978). Pour les populations amérindiennes le développement du Nord est surtout synonyme de marginalisation.

Dans cette optique, Schefferville représente un véritable laboratoire du développement nordique. Le développement induit par l'exploitation du fer par l'Iron Ore a peu profité aux Amérindiens. Ceux-ci ont vécu en marge de l'activité minière, spatialement, économiquement et socialement parlant. Ils n'ont profité directement des avantages de la présence de l'Iron Ore que sporadiquement, en tant que main-d'oeuvre disponible sur place, comme le démontre le tableau 1. Leur seul bénéfice fut l'accès aux services qu'offrait la proximité d'une agglomération organisée.

But et objectifs du mémoire

Le but premier de l'étude est de démontrer, à travers les relations Amérindiens-Blancs, la dynamique caractéristique du développement nordique. Notre recherche s'appuie sur le postulat suivant: dans le continuum historique de développement imposé par une culture différente, le type de développement imposé par l'Iron Ore a exclus les Amérindiens du développement économique et a contribué à leur marginalisation. L'hypothèse qui en découle est qu'en conséquence, Schefferville constitue le milieu de vie de deux communautés distinctes aux orientations et aspirations divergentes: la communauté amérindienne et la communauté blanche.

Le mémoire, fruit d'une démarche à la fois normative et historique, aborde dans un premier temps, la problématique scheffervillienne à la période post-fermeture de l'Iron Ore, ceci dans le but de situer les populations amérindiennes et blanches dans leur contexte actuel. Dans un deuxième temps, l'étude diachronique du processus de déstructuration du mode de vie amérindien permet de voir comment s'est établie la relation de dépendance de l'Amérindien vis-à-vis le Blanc. Finalement, ces aspects constituant le coeur de l'étude, l'analyse de l'attitude des Amérindiens face à la société majoritaire permet de dégager un portrait des communautés blanches et amérindiennes de Schefferville à partir des comportements suggérés par l'une et l'autre des ethnies. En effet les attitudes sont fonction des perceptions respectives de chacune des communautés.

La spécificité amérindienne et blanche de Schefferville, définie par rapport à leur perception du comportement des Indiens face à la société majoritaire, se fonde sur l'approche développée par Sommerlad (1968) pour les Aborigènes australiens, adaptée au contexte montagnais du Québec par Kurtness (1983).

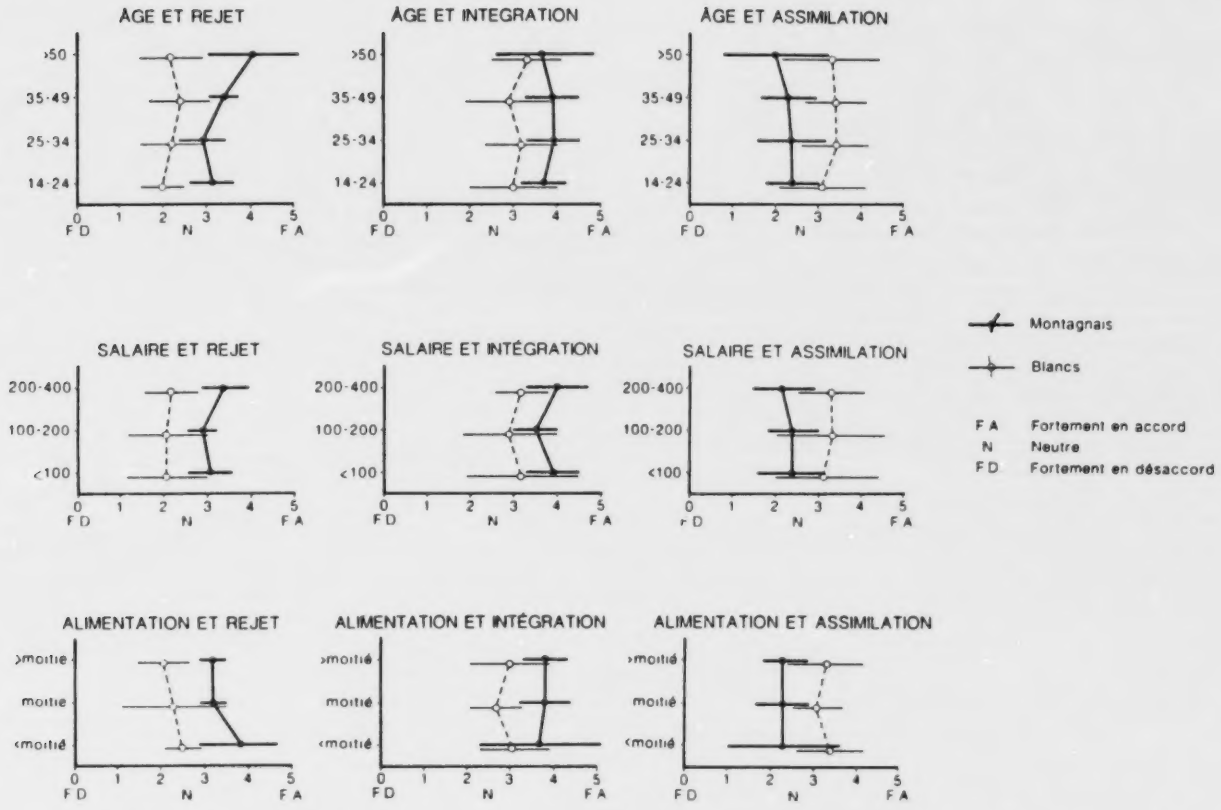


Figure 2. Représentation synthétique des questions regroupées selon les trois attitudes et les variables d'âge, de salaire et de type d'alimentation.

Attitudes des Amérindiens face à la société majoritaire

Méthodologie

Les données relatives aux attitudes ont été obtenues à partir d'un questionnaire, administré aux Blancs et aux Montagnais (pour des raisons hors de notre contrôle les Naskapis ont du être exclus de l'enquête). Ce questionnaire comprenait vingt-quatre (24) énoncés associés en terme d'identification collective selon trois axes: *l'assimilation* (ou fusion avec la société majoritaire avec perte d'identité ethnique), *l'intégration* (ou incorporation sélective d'éléments culturels de la société majoritaire mais aussi de maintien de l'identité au groupe de référence traditionnel et préservation des valeurs) et *rejet* (soit par l'abandon de liens avec la société majoritaire ou de réaffirmation de son identification au groupe de référence traditionnel (Sommerlad, 1968; Kurtness, 1983). Le répondant avait à indiquer son opinion sur chacun des énoncés sur une échelle de cinq (5) points allant du désaccord total vers l'accord total. Ce questionnaire faisait partie d'une enquête plus vaste réalisée à l'été de 1984 à Schefferville, visant également à déterminer les facteurs psychoculturels de choix de drogues et d'alcool chez les populations blanches et amérindiennes.

Les données relatives aux attitudes ont été mises en corrélation avec des données socio-économiques issues de la même enquête, données relatives à l'âge, le salaire hebdomadaire ainsi qu'au type d'alimentation, la dépendance à une nourriture de type de bois, par rapport à celle de type supermarché, reflétant l'importance des activités traditionnelles de chasse et de pêche chez les Amérindiens.

Résultats

La vision intra et inter-ethnique des relations Amérindiens-Blancs est présentée sous forme de graphiques où les variables socio-économiques sont mises en corrélation avec les attitudes.[1]. Ainsi, pour chacun des graphiques on retrouve en abscisse l'échelle d'opinion (désaccord total vers l'accord total) et en ordonnée les sous-groupes selon les variables socio-économiques (âge, salaire, type d'alimentation).

Les opinions de chacun des sous-groupe face aux énoncés associés aux différentes attitudes (six (6) énoncés pour le rejet, neuf (9) pour l'assimilation ainsi que pour l'intégration) ont été ramenées en un seul point représentant la moyenne observée pour le sous-groupe concerné. Ces moyennes sont représentées avec leur écart-type respectif.

De façon particulière, les constatations qui peuvent être faites à la lecture des graphiques de la figure 2 sont les suivantes:

a) au niveau intra et inter-ethnique

- la variable de l'âge amène une opposition entre jeunes Amérindiens et Amérindiens plus âgés. La position négative envers l'intégration (de même qu'envers l'assimilation) et la position nettement

pro-rejet de ces derniers attestent leur résistance aux changements. Par ailleurs une dispersion de l'opinion est constatée pour le même sous-groupe, l'écart-type étant de façon constante très étendu. Chez les Blancs, l'âge n'entraîne pas d'opposition systématique entre deux sous-groupes particuliers. Au niveau inter-ethnique, les écarts-types démontrent un certain partage d'opinion entre Amérindiens et Blancs:

- la variable du salaire indique, quant aux comportements des deux ethnies, que chez les Amérindiens ce sont ceux ayant les revenus les plus élevés et les plus faibles qui confirment les comportements. Par ailleurs, en regard des écarts-types on constate que les opinions des Amérindiens sont beaucoup plus homogènes que celles des Blancs. Enfin, l'opposition entre Amérindiens et Blancs est sensiblement moins importante dans le cas du salaire que dans celui de l'âge;
- la variable ayant trait au type d'alimentation différencie également les groupes malgré une certaine distorsion amenée par le nombre peu élevé de répondants Amérindiens dans la catégorie «moins de la moitié» et Blancs dans la catégorie «moitié». Au niveau intra-ethnique l'opinion amérindienne demeure très homogène par rapport à une plus grande dispersion chez les Blancs à en juger par les écarts-types.

En résumé, au niveau intra et inter-ethnique, la variable d'âge oppose le plus les groupes et sous-groupes entre eux. Les autres variables demeurent discriminantes mais à un moindre degré.

b) au niveau des attitudes

de façon globale les graphiques reflètent une certaine cohérence quant à la position des groupes ethniques face aux attitudes et ce, de façon constante pour l'ensemble des variables socio-économiques. Ainsi la position respective des courbes sur l'échelle d'opinion revèle la présence de deux groupes aux perceptions opposées: d'une part les Amérindiens davantage favorables à l'intégration (les moyennes se situant près de 4) mais relativement opposés à l'assimilation (avec des moyennes comprises dans la zone de neutralité, i.e. entre 2 et 3), d'autre part, les Blancs favorisant l'assimilation (les courbes tendant vers l'accord avec des moyennes comprises entre 3 et 4) mais non le rejet (la courbe se déplaçant vers le désaccord avec des moyennes tournant autour de 2).

Il ressort toutefois de façon particulière que le rejet constitue, chez les Amérindiens, l'attitude prônée par la population âgée (plus de 50 ans). On peut émettre comme hypothèse de ce comportement un renforcement des valeurs traditionnelles chez une population ayant connu un mode de vie ancestral davantage autarchique.

En conclusion

Schefferville est le lieu de rencontre de deux mondes aux orientations et aux aspirations divergentes. C'est le constat de deux communautés distinctes: celle des Blancs venus s'installer dans le Nord pour y faire ou refaire leur vie, celle des Amérindiens, présente depuis toujours, qui ont vu leur monde peu à peu transformé. C'est ce que nous avons voulu démontrer dans notre mémoire.

Ainsi, se basant sur le contexte propre à Schefferville nous avons montré dans un premier temps que les Amérindiens ont vécu en marge de l'activité minière, spatialement et socio-économiquement parlant. En effet, spatialement parlant, Schefferville représente deux milieux de vie différents: un milieu blanc avec la ville et ses services et un milieu amérindien un peu à l'écart, beaucoup moins organisé, comptant sur les ressources disponibles à la ville. Au niveau socio-économique, peu d'Amérindiens ont travaillé pour l'Iron Ore exception faite de la période de construction de la ville et du chemin de fer.

Par ailleurs, une vision diachronique des relations entre Amérindiens et Blancs a permi de saisir le processus conduisant à la déstructuration du mode de vie traditionnel des Amérindiens et à leur marginalisation. Le processus d'acculturation a conduit à la définition d'un nouveau mode de vie où sont présents des modes de production concurrents issus des grandes périodes économiques de l'histoire amérindienne: le mode traditionnel (activités liées à la subsistance), «de contact» (trappage économique) et moderne (salaires, redevances, paiements de transfert). La différence culturelle liée à des modes de vie distincts implique des comportements particuliers à chacune des ethnies contribuant ainsi à leur singularisation.

Enfin, cette singularisation se confirme dans la perception des Amérindiens et des Blancs sur les attitudes des Amérindiens envers la société majoritaire. L'enquête effectuée en 1984 à Schefferville a démontré la divergence d'attitudes entre Montagnais et Blancs, les premières refletant l'intégration, les secondes, l'assimilation.

En conclusion, nous dirons qu'au-delà de sa dualité, Schefferville est aussi l'héritage de l'histoire, une autre page déjà tournée du «mal-développement» du Nord.

Références

Bradbury, J., Wolfe, J.M., 1983. Recession, planning and socio-economic change in the Quebec — Labrador iron-mining region. MSARP no. 38, Centre for Northern Studies and Research, McGill University.

Conseil de la MRC de Caniapiscau, 1985. MRC de Caniapiscau. Elément d'une gestion harmonieuse. Document de consultation. Conseil de la MRC de Caniapiscau. Fermont.

Desy, P., 1963. Acculturation et socio-économie chez les Montagnais et les Naskapis du lac John près de Schefferville. M.A. géographie, Université Laval, Québec.

Gregoire, P., 1976. Impact du développement minier sur la population montagnaise de Schefferville. Conseil Attikamek-Montagnais, Village des Hurons.

Hamelin, L.E., 1974. Nordicité canadienne. Collection Géographie. Les cahiers du Québec/Hurtubise HMH, Montréal.

Kurtness, J., 1983. Les facteurs psychologiques des parcours de l'acculturation chez les Montagnais du Québec. Thèse de doctorat, Ecole de psychologie, Université Laval.

Morrissonneau, C., 1978. La terre promise: le mythe du Nord québécois. Montréal. Coll. Ethnologie. Cahier du Québec, Hurtubise HMH.

Sommerlad, E.A., 1968. The importance of ethnic identification for assimilation and integration: a study of Australian aborigines' attitudes. B.A. Honours, University of Sydney.

Footnotes

1 Trois séries de graphiques illustrent la perception des Amérindiens et des Blancs sur les attitudes que devraient adopter les Amérindiens face à la société majoritaire. La première série présente le comportement de chacun des groupes et sous-groupes (selon les variables) par rapport à chacun des énoncés du questionnaire. La seconde faisant l'objet de cet article, résume l'ensemble des énoncés montrant ainsi les tendances observées pour chacun des groupes ethniques. Une troisième série synthétise l'information et montre de façon synoptique, la position respective selon les variables socio économiques retenues, des Amérindiens et des Blancs.

APPROPRIATE EDUCATION FOR THE INUK GEOGRAPHY STUDENT

Ken Beardsall

Departments of Geography and Native Studies, Trent University, Peterborough, Ontario K9J 7B8

Level: Bachelor's

Abstract

The northern school system is frequently criticized by Inuit for its regional and cultural inappropriateness. A project was undertaken by the author to develop an experimental geography curriculum with an information base of Inuit origin. The location of the research for this project was Coral Harbour, on Southampton Island, in the N.W.T. Information was gathered about the Inuk understanding of the atmosphere, the land, the sea ice and other elements of the discipline southerners call physical geography. As was expected, community knowledge in this field was extensive, and the primary objective, in this project, became to survey this resource to determine how it might best be harvested and utilized in a school curriculum. A map showing Inuk place names and a glossary of Inuk geography are provided as a sample of the achievements of Inuit in geography.

The other important element of this inquiry was to gain insight into Inuk teaching and learning practices. It was observed that these methods are very effective and should be used to increase the effectiveness of any curricula in northern schools.

The methodology employed, while in the community, involved a high level of cultural integration and a general abandonment of the obtrusive, formal academic procedure.

Key words: Inuk-Inuit, Coral Harbour, schools, physical geography, local knowledge, curriculum.

Résumé

Les Inuit critiquent fréquemment l'appareil scolaire du Nord à cause de son inadéquation sur les plans régional et culturel. L'auteur a mis sur pied un programme d'élaboration d'un enseignement de la géographie fondé sur une base de données d'origine inuit. Les recherches pour étayer cette élaboration se sont déroulées à Coral Harbour, dans l'île Southampton, T. N.-O. L'auteur s'est informé au sujet des connaissances inuit sur l'atmosphère, le sol, la glace de mer et autres éléments de ce que les gens du Sud appellent la géographie physique. Comme l'auteur s'y attendait, les connaissances de la collectivité inuit en ce domaine étaient variées. En conséquence, le premier objectif du programme devint de faire le tour de cette ressource pour trouver la meilleure façon de la recueillir et de l'introduire dans l'enseignement scolaire. L'étude fournit une carte des noms de lieux en langue inuit et un glossaire inuit de géographie pour montrer les réalisations des Inuit en cette matière.

L'étude des méthodes d'enseignement et d'apprentissage des Inuit constitue un autre volet du programme. On avait observé que ces méthodes sont très efficaces, et qu'il faudrait les utiliser pour accroître l'efficacité de l'enseignement de toute matière dans les écoles nordiques.

Les méthodes employées pour les recherches dans la collectivité inuit nécessitaient une totale immersion culturelle et l'abandon général des méthodes universitaires officielles, trop importunes.

Mots-clés: Inuit, Coral Harbour, écoles nordiques, géographie physique, connaissances des gens du pays, enseignement.

Introduction

The traditional Inuk life style involves an intimate relationship with the physical environment. The succession of countless generations in the Arctic has resulted in the development of a great stock of knowledge concerning the landscape, the atmosphere, and the sea as well as the ice and snow found within each of these media. Southern Canadians would classify members of its society who were learned in such phenomena as physical geographers; hence one could describe the Inuk culture as consisting of a large number of geographers. Research was undertaken to explore this world of geographical knowledge during the summer of 1986, in the community of Coral Harbour (called Salliq in Inuktitut) in the Keewatin district of the NWT.

At the 1986 circumpolar Inuit Youth Camp at Ikpik Bay on Baffin Island, it was resolved that the educational system is failing to satisfy the needs of the Inuit, with one of its major faults being its lack of indigenous content (Ikpik 86). This sentiment was also expressed by many current and former students in Salliq. The curriculum which is used has southern roots, as do its instructors, with the problem that often the concepts presented are completely extraneous to the Inuk reality. The negative implications of this are many.

When travelling with Inuit on a hunting trip, one becomes aware of the great enthusiasm the young people have for learning about the land. There is considerable pride attached to finding a landmark and then negotiating one's way home. When an older person relates some of his knowledge to the younger generation, the inevitable response will be to stop, listen, and learn, for they all know that this information is important. Much of the material gathered in this research

indeed was collected from young adults, indicating that there is a great deal of learning going on outside the school. There were, however, gaps in the environmental understanding which these young people possessed. Frequently, the term in Inuktitut for some environmental phenomenon would be forgotten, as would many place names. The other aspect of this knowledge which seemed to be missing was explanation. It seems to be a part of the Inuk culture to refrain from asking, "why?". However, it was found that there was indeed some interest in any scientific explanations which I could provide. One of the elders told me that people used to have more explanations for things but that most of them have been forgotten since the arrival of the Quallunuit (the white race). The traditional teaching practices are rather limited today, with the young people spending so much time in school. There is time for teaching only the things which one needs to survive while out on the land.

The excellence of the Inuk understanding of the environment, together with the enthusiasm of the young people to learn about it, seems to expose at least a partial solution to the current educational dilemma in the North. Physical geography could be taught to Inuit using the phenomena and approaches with which they are already familiar, adding southern scientific explanations in a culturally appropriate manner.

Methods

Any consultative research project, such as this one, is entirely dependent upon response from the community. Naturally enough, people are not usually willing to open their doors to a complete stranger and answer anything they are asked. In this case, site selection was part of the methodology used to reduce this problem. I had visited Salliq in 1977 as a participant in a school exchange and had since maintained enough contact to be welcomed back by a few of the Inuit involved. This was an enormous advantage to me as a researcher but was certainly not a *carte-blanche* to the Inuk culture. In fact, it was quickly discovered that it is not advantageous to bear either the title or the character of a *researcher* unless one can afford to pay up to $200 for a single interview. An alternative method of gaining information is to put away the tapes, pens, and paper for a few weeks and to concentrate instead on attaining community acceptance and cultural integration. Attempting to speak Inuktitut, eating raw walrus, and allowing oneself to be the object of much laughter will, in the end, bring many more results than a sheet of questions and a tape recorder. After one had been accepted, however, the interview method could successfully be put to use.

The normal course of a day in Salliq involved "hanging out" at The Bay (The Hudson's Bay Company) or The Co-op, talking about hunting and fishing excursions. Within these chats, one could learn the names of different places or different environmental processes. This information was written down later, for it is unnatural and rude to be writing while someone else is talking to you. This kind of methodology was also used at night while *visiting*[1] or *walking around*.[2] The majority of the information, however, was collected while out on the land (travelling away from the community to hunt or to fish). Here the physical environment is always a major topic of conversation, and it is natural to ask questions and natural for them to be answered. An example of this type of learning was an occasion on which two of us were lying on the ground waiting for some geese to fly over, watching the shimmering of the landscape through evaporating water. My companion explained to me that when this process, called uruamiak, makes it look like the land is going up, then there will be wind coming. This insight could be the basis for a much more appropriate and understandable lesson in evaporation at school.

Travelling on the land with Inuit reveals how well these people can navigate across what appears to be a white, featureless landscape. Though maps and compasses are occasionally used, they are seldom depended upon. Memory is used and relied upon more than anything else.

The methodology which was used to gain an understanding of the current education system and its associated problems was somewhat different from that used for the geographical component. The sources of information were much more diverse in that they included white teachers and principals, current and former Inuk students, and classroom assistants. Information was also gained through documents such as the curriculum guide for Social Studies K-9 (Northwest Territories Education, 1979), the final report of the Northwest Territories Legislative Assembly Special Committee on Education (Learning- Tradition and Change in the Northwest Territories, 1982), and through my attendance at the aforementioned Inuit Youth Camp at Ikpik Bay.

The youth camp included a workshop dealing exclusively with education, which proved valuable in bringing out the major concerns as well as giving me the opportunity to compare Salliq's situation to that of the other northern communities.

Figure 1. A sample of Inuk ice terminology.

Inuktitut	English
aussuituq	glacial ice
ikaruq	ice ridge (also reef)
ikiqtiniq	water between ice and land
ipjuiaq	thick sea ice
mauliriak	good ice for seal holes
nilak	ice to be melted for water
nunirq	ice which joins the island to the mainland — this will not occur every winter
pirqalujak	iceberg
poktaq	loose floe ice
qoak	frozen meat or any other item
qoasak	lake ice
sikku	sea ice in general
sikoak	extremely thin ice
sikuliak	new ice — thin yet thicker than sikoak
sikuliaviniq	new ice yet older than sikuliak
sina	edge of fast ice (floe edge)
tuvalak	large mass of floe ice
tuvak	large fragments of tuvalak
tuvaviniq	pancake floe just large enough to stand upon

Results

Inuk Geography

The Inuk who has a good understanding of his physical environment could be called an Inuk geographer and his discipline labeled Inuk Geography. A good index of the depth of Inuk geographical knowledge is the language, Inuktitut.

Included in this paper is a small sample of the terminology used by Inuit to describe different types of ice (Fig. 1). As the Inuk language varies considerably across the Arctic, these terms may be unique to the Keewatin region. Some of the terms are rather specific and can be equated with terms in English which are used only by scientists; yet in Salliq these are all household words. Figure 1 is a part of a glossary in Inuk Geography which is being constructed from the summer research project. This glossary will be an element of an information package which will be given to the school in Salliq to be used, if so desired, as the basis for a geography curriculum. This glossary, as well as the whole information package, could have its contents enlarged, improved, and updated by the community itself, unlike the current geography text.

Figure 2. Map showing a sample of Inuk place names on Southampton Island (Salliq). The following are the names which correspond with the numbers printed on the map: 2. Nuvua; 6. Rkulutualuq; 10. Kuk; 11. Manimaniq; 13. Nunariaq; 14. Aligjivik; 25. Itijuakjuk; 34. Itijuarjualaq; 35. Rkikitaugaq; 39. Ujarasukjualuk; 42. Tuniqmiuk; 43. Tunimiu Nuvuajualu; 49. Pangkagitualaq; 55. Nuvualuk; 89. Itijugaluk; 95. Rkikitaugalik; 99. Mamisuituq; 109. Rkakutajak; 135. Akturuarjuk; 136. Akpatujuak.

Another major element of this information package is a map of the island Salliq, with all of the traditional Inuk names upon it. A sample map has been provided in this paper (Fig. 2). Figure 2 is an incomplete version of what will be the finished product. A man in the community had gone to the older people and collected a list of 136 place names from all over the island. Each of these names has been given an associated number. However, only 20 of the 136 have had their location on the map determined at this point in time, thus explaining the haphazard numbering system of figure 2.

Maps are of great interest to Inuit generally, and they can look at them for hours, allowing stories to flow out of each place to which they point their finger. The hamlet foreman told me that he used to have a big map of Salliq in the office but that he had to take it down because his employees spent too much time looking at it. When I enquired about local people drawing maps, the general consensus was that they could draw memory maps if they wanted to but that they never did. When George Sutton visited Salliq in 1929, there were no maps available, so two of the local Inuit drew some for him to use as he navigated around the coast. These maps have been printed by Edmund Carpenter in his book *Eskimo* (Carpenter *et al.*, 1959), and when compared to a modern map they are extremely detailed and accurate. The availability of government topographic maps today is likely the main reason why local people are not drawing them any more.

Another skill which is rapidly becoming forgotten is weather prediction. Most of the older people are still quite adept at this, although few of the young people are really working at it. Two of the young people are being trained to become official observers at the local weather station, one of them being the son of the community weather expert. Perhaps this weather station has a discouraging influence upon students wishing to pursue the traditional methods. It takes a long time to become proficient at the art of weather prediction since so much of it involves remembering patterns and their associated outcomes. It was discovered during the research project that the old people are sensitive to climatic change over the years, making the observations that it never gets as cold as it once did but that it seems to be much more windy. It was observed that the fog (arctic haze), which used to obscure a man's sled dogs in front of him on a bitter cold day, seldom occurs now. These types of insights could prove valuable in the classroom when discussing global climatic trends.

Conflicting educational institutions

An institution such as an educational system is something which was evolved from a particular society so as to satisfy its distinct needs (Berger and Luckmann, 1966). In Salliq and other Inuk communities, the young people are faced with two different societies and are forced to decide in which one they should be educated. There are many who would choose a southern style of education so as to get a job, but they despise living away from their settlement and also find the academic subjects of high school tedious. Whether students choose to study in Iqaluit, Yellowknife, or Rankin Inlet, their educational experience will involve living in a residential school (unless they have relatives with whom to board). The residential environment provides very little of the freedom which characterizes Inuit lives. Rebellion against this

treatment often takes the form of drinking, fighting, and smoking narcotics, which inevitably leads to the exclusion of the student from this form of education.

Those who choose to remain in the community after grade 9 in order to follow the traditional education system are often better off as a result. While many of the others were away at school, gaining nothing but depression, the youth in Salliq were getting ahead in the world of hunting, trapping, child care, snowmobile repair, and similar practical skills.

A geography programme designed from Inuk knowledge would be direct employment preparation for either set. However, it might make school more bearable and would perhaps stimulate students to continue further in their schooling. This type of programme, though far from equalling an education on the land, would see students less ignorant in the ways of their environment than are the graduates of the current system. One would hope that this geography programme would evolve in such a way that its graduates would eventually become its instructors.

Building a bicultural system

The implementation of Inuk Geography in northern schools is no small task. Elements which must be considered are the information base, teacher training, and the governmental processes involved in instituting a major change in educational policy. There are not, in my opinion, a large number of Inuit who would care to tackle the "red tape" involved with instituting this programme from scratch. It would certainly be helpful to provide the Community Education Society (CES) with a step-by-step guide explaining what changes are involved in the procedure and how these could be achieved.

Certainly, there needs to be much more information collected in the field of Inuk Geography, since what I could provide from my research is but a drop from the bucket of knowledge which exists. One organization particularly suited to doing this kind of research is the Inuit Cultural Institute (ICI). They have been doing research into their own culture for many years now, and it would certainly boost their governmental funding if they could contribute directly to the northern schools.

Some form of teacher training is essential to making this system work, for if the teachers can neither grasp nor synthesize the material, the students will have little access to it. The training could take the form of a guide which would introduce them to the rationale behind the programme and then to the information package itself. Sample lessons would be provided as a means of showing how the information could be taught in a meaningful manner.

Conclusion

The potential of a geography curriculum with an information base of local origin is extensive in any culture. It seems to be a particularly appropriate concept for Canada's Inuit, though, since the knowledge within their society is so vast and the current educational and youth problems so numerous. Possibilities also exist for using local knowledge in other disciplines, such as biology or history, where there is also a great deal of understanding. It is important, however, that a large scheme like this be instituted slowly so that the inevitable wrinkles can be ironed out without significant disturbance of the students' education.

Acknowledgments

Funding for this project was provided by the Northern Scientific Training Programme of the Department of Indian Affairs and Northern Development and the Royal Canadian Geographical Society, and this was greatly appreciated. Thanks must also go to Johnny Ningeongan, who collected the place names, to Inuapik and Nellie Ell, who allowed me to stay in their home for two and a half months, and to my translators — Tommy Nakoolak and Tommy Paliak. I extend my thanks to the Inuit Youth Council for inviting me to observe at the Ikpik Bay youth camp.

References

Berger, P.L. and Luckmann, T. 1966. The Social Construction of Reality — A Treatise in the Sociology of Knowledge. Garden City, New York: Doubleday and Company Incorporated, 219 pp.

Carpenter, E., Varley, F.L. and Flaherty, R. 1959. Eskimo. Toronto: University of Toronto Press.

Ikpik 86. Resolutions of the 1986 International Inuit Youth Camp. Inuit Youth Council of the Inuit Tapirisat of Canada. Ottawa. (In press).

Northwest Territories Department of Education 1979. Social Studies K-9. Yellowknife, 240 pp.

Northwest Territories Legislative Assembly Special Committee on Education 1982. Learning — Tradition and Change in the Northwest Territories. The Final Report. Yellowknife.

Footnotes

1 Visiting is a well developed social structure in Salliq with a number of cognitive rules governing it.

2 Walking around is another old yet essential social practice, which usually involves the young people. This is often how members of the opposite sex can get together without the embarrassment of a visit. Walking around the town 16 times is not out of the question.

LES BEAUX SAUVAGES DE LA FLORIDE, DE LA VIRGINIE ET DU CANADA (1675–1723) LA MUSÉOLOGIE RENCONTRE L'ANTHROPOLOGIE

Denyse Bilodeau[1] et Claude Gagnon[2]

[1]*Département d'anthropologie, Université Laval, Ste-Foy, Quebec G1K 7P4*
[2]*Arts et traditions populaires, Université Laval*

Niveau: D. Bilodeau, Doctorat
C. Gagnon, Doctorat

Résumé

Nous, Denyse Bilodeau (étudiante au doctorat en anthropologie à l'Université Laval) et Claude Gagnon (étudiant au doctorat en arts et traditions populaires à l'Université Laval) avons organisé, en tant que conservateurs-invités, au Musée du Séminaire de Québec, une exposition intitulée *Les Beaux Sauvages de la Floride, de la Virginie et du Canada (1675–1723)*. Cette exposition, qui a lieu du 8 juin au 30 août 1986 et qui est subventionnée par le Conseil des Arts du Canada, se propose de montrer, à partir de quelques oeuvres sur papier du Jésuite missionnaire Louis Nicolas (1634?–1682?) et du peintre de cour Bernard Picart (1673–1733), comment l'amérindien a été représenté, au tournant des XVII[e] et XVIII[e] siècles, selon la vision européenne du mythe du «bon sauvage».

Dans le cadre d'une communication, à la conférence nationale des étudiants en études nordiques, nous souhaitons livrer aux chercheurs réunis de l'information sur la conception anthropologique de cette exposition soit principalement sur sa problématique — qui implique la question fondamentale de l'ethnocentrisme — et sur sa méthode — c'est-à-dire la sélection des oeuvres et son interprétation. Cette communication sera agrémentée par la présentation de diapositives des oeuvres exposées dans l'exposition.

Mots-clés: Muséologie, anthropologie, iconologie, amérindiens, altérité, représentation, ethnocentrisme, conquête, Nouveau-Monde.

Abstract

We, Denyse Bilodeau (doctoral candidate in anthropology at Laval University) and Claude Gagnon (doctoral candidate in popular arts and traditions at Laval University) have, as guest curators at the Museum of the Séminaire de Québec, organized an exhibition under the title *The Handsome Savages of Florida, Virginia and Canada (1675–1723)*. This exhibition, which runs from June 8 to August 30, 1986 with funding from the Canada Council, uses a number of works by the Jesuit missionary Louis Nicolas (1634?–1682?) and the court painter Bernard Picart (1673–1733) to show how the Amerindian was represented, at the end of the 17th and the beginning of the 18th centuries, in accordance with the European view of the myth of the "good savage".

We hope that the paper we will be giving at the National Student Conference on Northern Studies will give us the opportunity to inform the researchers attending the conference about the anthropological concept of this exhibition, the main emphasis being on its theoretical approach — which implies the fundamental question of ethnocentrism — and its method — that is to say, the selection of works and the interpretation thereof. Presentation of the paper will be accompanied by slides of the works exhibited.

Key words: Museology, anthropology, iconology, Amerindians, otherness, representation, ethnocentrism, conquest, New World.

Introduction

Dans notre exposition *Les Beaux Sauvages de la Floride, de la Virginie et du Canada (1675–1723)*, subventionnée par le Conseil des Arts du Canada, nous avons voulu présenter au visiteur des oeuvres qui témoignent de la représentation du «bon sauvage» qui a cours en Europe, au tournant des XVII[e] et XVIII[e] siècles.

À partir de la collection des oeuvres sur papier du Musée du Séminaire de Québec, nous avons sélectionné des facsimilés de Louis Nicolas (1634–1682?) et des gravures de Bernard Picart (1673–1733), oeuvres qui offrent des perceptions du «bon sauvage» marquées par des expériences différentes. À cet effet, soulignons que le jésuite missionnaire Louis Nicolas a reproduit des portraits d'Algonquiens et d'Iroquois à partir d'un séjour en Nouvelle-France (1664–1675) et que Bernard Picart, qui n'est jamais venu en Amérique, a représenté le «bon sauvage» en s'inspirant des gravures de Théodore de Bry (1528–1598) qui a gravé d'après des dessins des artistes Jacques Lemoyne de Morgues (?–1588) et John White (XVI[e] siècle). La représentation de l'Amérindien par Nicolas est donc empreinte de son expérience du Nouveau-Monde tandis que celle de Picart est plutôt stimulée par l'imaginaire européen.

Par cette exposition, nous avons cherché à faire prendre conscience au visiteur que ces deux types de représentation de l'Amérindien, présentées dans les oeuvres de Nicolas et de Picart, concordent avec l'ère des grandes conquêtes coloniales entreprises par l'Europe dès le XVI[e] siècle et qu'elles véhiculent des préjugés ethniques et raciaux, favorables ou défavorables, à l'endroit des autochtones de l'Amérique septentrionale.

Tout au long de cette communication nous montrerons, à l'aide de diapositives illustrant les oeuvres exposées, que ces perceptions de l'Amérindien se déplacent entre le réel et l'imaginaire et qu'elles contribuent, plus qu'autrement, à nier sa culture au profit de la culture du conquérent européen.

Les commentaires que nous élaborerons sur les oeuvres s'inspirent, principalement, des sources suivantes. Dans le cas des oeuvres de Bernard Picart, nous nous sommes limités au livre des abbés Banier et Mascrier *Histoire générale des cérémonies, moeurs et coutumes religieuses de tous les peuples du monde* (1741) lequel présente, en plus de toutes les gravures de B. Picart que nous avons exposées, un commentaire sur chacune d'elles. Comme notre but est de mettre l'accent sur l'ethnocentrisme qui prévaut dans la représentation que l'Européen se fait de l'Amérindien, à cette époque, nous avons cru pertinent de rapporter aussi intégralement que possible l'information contenue dans ce livre. Dans le cas des facsimilés de Louis Nicolas, nous nous sommes référés au texte de François-Marc Gagnon «L'expérience ethnographique de Louis Nicolas" (1979) et à ceux de Anne-Marie Sioui «Qui est l'auteur du Codex Canadiensis?» (1979) et «Les onze portraits d'indiens du Codex Canadiensis» (1981).

Le préambule ci-dessus a servi à présenter la série de diapositives constituant notre contribution à la Conférence nationale des étudiants en Études nordiques. Bien entendu, nous ne pouvons pas reproduire cette série, et nous la remplaçons par l'exposé qui l'accompagnait, en l'illustrant par quelques exemples des diapositives. Ces illustrations portent un numéro de référence.

This preamble normally serves to introduce the slide show which was our contribution to the National Student Conference on Northern Studies. We cannot, of course, present the slides here. Instead, we present the commentary on the slides with a few examples of them as illustrations. The illustrations are indicated by Figure numbers.

L'Amérique septentrionale suivant les
nouvelles observations des
Mess. de l'Académie Royale des Sciences, etc.

Datant de la fin du XVII[e] siècle, cette carte (pas incluse) dont l'auteur est anonyme illustre l'Amérique septentrionale telle qu'elle était représentée à cette époque.

Si nous avons choisi cette carte, c'est que les gravures exposées dans cette salle couvrent trois lieux spécifiques de l'Amérique septentrionale: la Floride, la Virginie, le Canada. Alors, comme tout le monde le sait sans doute, la Floride occupe à cette époque, en plus de la péninsule que nous lui connaissons, tout le domaine connu aujourd'hui sous les noms de Louisiane, Alabama, Texas, Nouveau Mexique. La Virginie située au nord de la Floride correspond à ce que nous connaissons d'elle aujourd'hui et le Canada, toujours plus au nord, est constitué de ce qu'il est convenu alors d'appeler la Nouvelle-France.

Noter que c'est la partie Est de l'Amérique septentrionale qui nous intéresse, la partie Ouest n'étant pas encore conquise.

P. Aveline (1702–1760)
Bernard Picart

Bernard Picart, né en 1673 — mort en 1733, est peintre de cour, en France, sous le règne de Louis XV.

Ayant à répondre aux commandes du Roi et des nobles, ses dessins, peintures et gravures seront de pur style classique. Picart a principalement illustré des scènes bibliques et des scènes exotiques.

Ses gravures sont en général des commandes pour des livres condensant des récits de voyages dont celui des Abbés Banier & Mascrier exposé dans cette salle. Héritier des idées de la Renaissance, c'est par un traitement pictural classique que Bernard Picart représente les sauvages: leurs corps dégagent harmonie, équilibre et perfection selon des modèles prisés par les européens. Tout dans les formes, les attitudes, les poses et les accessoires rappelle les statues antiques: la rondeur des mollets et des fesses, les drapés et les toisons dont les personnages sont parés, le hanchement des corps, les poses et contre-poses, la longue chevelure nattée des femmes, leurs cheveux bouclés . . . De plus, à cette époque, la religion occupe une place de premier rang. Ainsi les oeuvres produites revêtent une haute signification morale; divers rituels reliés à des cultes aussi diversifiés que la mort, la renaissance, les semailles et les moissons, les mariages sont représentés. Quasi-invariablement, on verra que des prêtres, devins, magiciens et/ou idoles président ces rituels, comme si on avait voulu montrer par là aux européens que même les plus sauvages des humains ne sont pas incultes; aux européens aussi alors de croire et d'avoir la foi.

Bernard Picart (1673–1733)
Le grand sacrifice des canadiens
à Quitchi-Manitou ou le grand esprit
(Fig. 1)

Selon le baron de la Hontan, les «sauvages» n'offrent jamais de personnes vivantes à Quitchi-Manitou, mais ils brûlent en son honneur des marchandises qu'ils trafiquent avec les français. Ce sacrifice, qui rappelle la cérémonie rituelle du «potlach», a lieu un jour de beau temps et chaque sauvage doit offrir au Dieu un don précieux qu'il porte au bûcher. On allume le feu quand le soleil est couché. Ce rituel est accompagné de chants, de prières et de danses et les prières qui sont addressées à Quitchi-Manitou concernent surtout la demande de protection contre les ennemis, la mort, les mauvaises récoltes, les intempéries, etc.

Remarquons ici l'interprétation picturale de Picart: il dessine les corps des amérindiens à la manière grecque, il ondule les cheveux, il habille l'autochtone avec des drapés sculpturaux, il représente dans le décor nordique des palmiers imaginaires et dessine dans ces offrandes offertes à Quitchi-Manitou des tapis, des draperies et des tissus européens. Le seul élément de culture amérindienne vérifiable est cette maison longue des peuples sédentaires.

Bernard Picart (1673–1733)
Rejouissances des peuples du Canada,
pendant que l'on porte le defunt, à la Cabane des morts.
Convoi funèbre des peuples du Canada

Selon le Père Hannepin, missionnaire qui est venu au Canada, les rituels funéraires sont toujours accompagnés de festins donnés en l'honneur du mort et ces festins se déroulent dans la joie.

Concernant le convoi funèbre, on remarque la hiérarchie des personnages: les hommes dirigent la procession, les femmes et les enfants suivent. Ce modèle hiérarchique de la procession funèbre en Canada est fort semblable à celui qu'on retrouve en Europe. S'agit-il d'une transcription d'une

LE GRAND SACRIFICE des CANADIENS à QUITCHI-MANITOU ou le GRAND ESPRIT.

Figure 1.

pratique culturelle européenne sur une pratique autochtone produite par le graveur ou s'agit-il vraiment d'une coutume amérindienne réelle, on peut se le demander?

Bernard Picart (1673–1733)
Sauvage qui allume une Allumette,
pour aller trouver sa maîtresse
Sauvage en conversation avec sa maîtresse
étant assis sur le pied de son Lit
Sauvage dont la maîtresse se cache dans sa
couverture ne voulant pas le recevoir
Sauvage dont la maîtresse éteint l'allumette
pour le recevoir

Il est au Canada une pratique que le Baron de la Hontan a observée et qu'il dit s'appeler: «courir l'allumette». Ainsi dès qu'un jeune homme trouve une jeune femme à son goût, il se rend, la nuit venue, à son chevet. Il se pare pour cette occasion d'une petite torche allumée et entre dans la couche de sa belle: si celle-ci éteint de son souffle la flamme de la torche, le jeune amant entrera dans les couvertures avec elle, si la jeune femme se cache sous ses couvertures, le jeune homme devra partir, mais quelquefois aussi, la jeune femme permettra à son prétendant de s'asseoir au pied de son lit pour discuter un peu et si un autre jeune homme arrive qu'elle préfère, il devra céder la place au dernier.

Noter la petite chambrette de la jeune amérindienne et la porte à clapet de ce lieu se rapprochant davantage des chambres conjugales occidentales que des maisons sans division et sans porte des peuples sédentaires amérindiens.

Bernard Picart (1673–1733)
Cérémonie nuptiale du Canada
Manière dont les peuples du Canada font le divorce

Toujours au Canada, on rapporte qu'avait lieu des cérémonies reliées au mariage et au divorce. Lors de la cérémonie du mariage, les futurs époux tiennent chacun par leur extrémité un bout de bois, témoin de l'union conjugale. Ce bout de bois, une fois la danse rituelle d'épousailles exécutée, ici sur un tapis de «Turquie» ou de «Perse», sera cassé en autant de parties que d'assistants à la cérémonie.

Ces bouts de bois seront rassemblés et conservés dans un coffret. Dans l'éventualité d'un divorce, ils seront jetés au feu, la cérémonie se déroulant dans le même lieu que le mariage.

Planche tirée du livre du Baron de la Hontan
Mémoires de l'Amérique Septentrionale ou
la suite des voyages de Mr. Le Baron De La Hontan,
tome second, Amsterdam, 1705

Par ce livre, on peut observer certains emprunts faits par Picart. En effet, le même rituel de séduction dit «courir l'allumette» est présenté ainsi que la cérémonie du mariage. A l'inverse de Picart cependant, les corps ne sont pas ici de pur style classique, mais plus près de la réalité. Notons au passage que le tapis de «Turquie» dessiné par Picart fait ici place à une natte, véritable élément de la culture matérielle des amérindiens.

Bernard Picart (1673–1733)
Jongleur qui vient guérir un malade
Esclaves qui pleurent le mort
Les parens demandent au défunt la cause de sa mort
(Fig.2)

Soulignons que cette gravure de Picart apparaît dans le livre des Abbés Banier et Mascrier *Histoire générale des cérémonies, moeurs et coutumes religieuses de tous les peuples du monde*. Ce livre est publié à Paris en 1741 et son genre littéraire est celui du récit de voyages fort populaire en Europe en cette époque de conquête et de découvertes. Il contient entre autres des extraits de récits de voyages du Père Hennepin et du Baron De La Hontan en Amérique septentrionale, récits à partir desquels notre commentaire s'inspire.

La gravure de Picart, sur laquelle le livre des abbés Banier et Mascrier est ouvert, représente le rapport qu'entretiennent les amérindiens du Canada avec le jongleur, c'est-à-dire le magicien ou le sorcier. A ce propos, dans le livre de Banier et Mascrier, le Baron de la Hontan décrit ce jongleur comme étant un personnage considéré de façon marginale dans la société. La Hontan le décrit comme quelqu'un ayant souffert d'une maladie et qui ne s'en serait pas entièrement remis. Le baron rapporte également que le jongleur chante, danse et hurle et suce le malade en quelques parties souhaitant ainsi faire évacuer, de son corps, le mauvais esprit qui s'y loge. Toutefois, le baron porte un jugement lorsqu'il dit que le jongleur exécute la danse de Saint-Guy plutôt que d'y voir une cérémonie de transe.

Bernard Picart (1673–1733)
Kiwasa idole des virginiens
Le dieu des vents, autre idole des virginiens

Nous voici maintenant un peu plus au sud, en Virginie. Nous sommes à cette époque en pleine recherche d'un passage pour les Indes. Cette gravure a tôt fait de nous le rappeler. Pour la première fois, Picart ponctue différemment les traits de certains personnages.

Sans doute pour marquer une hiérarchie au sein de l'organisation sociale, Picart orientalise les traits de l'idole principale des virginiens. Kiwasa ressemble par sa pose à un Bouddha, par son faciès à un oriental et par ses vêtements à un personnage sans contredit bien élevé dans l'échelle sociale.

La gravure du bas représente une autre idole, dont la couleur de la peau tranche avec les autres personnages dessinés par Picart.

Bernard Picart (1673–1733)
Prêtre de la virginie, vû du côté droit
Prêtre de la virginie, vû du côté gauche
Magicien de la virginie

On retrouve encore une représentation marquant la hiérarchie sociale dans le représentation des prêtres et magiciens de Picart.

Prêtres et magiciens, nous rapportent les abbés Banier et Mascrier, s'occupent des affaires publiques: c'est à eux qu'on s'adresse pour prédire le déroulement des guerres, pour connaître les bons moments de la semence, pour guérir les malades.

JONGLEUR qui vient guerir un MALADE. *ESCLAVES qui pleurent le MORT.*

Les PARENS demandent au DÉFUNT la cause de sa MORT.

Figure 2.

On dit que «ces ministres s'efforcent de s'attirer la vénération publique par la manière effroyable dont ils se barbouillent tout le corps, par la singularité de leurs habits et par l'arrangement de leurs cheveux» (Banier et Mascrier).

Bernard Picart (1673–1733)
Les virginiens, adorent le feu, et se réjouissent,
apres avoir été délivrés de quelque danger considérable

A chaque retour de guerre, des fêtes ont lieux: on se réunit autour du feu auquel on accorde une dévotion particulière et les prêtres, dont la tête est ornée de queues d'animaux, président ce culte du feu.

Bernard Picart (1673–1733)
Tombeaux des rois de la virginie

Comme le rapporte le baron de La Hontan, dans le livre des abbés Banier et Mascrier, les corps des rois de la Virginie sont conservés selon des techniques bien précises. D'abord, la peau du dos est fendue et arrachée et les tripes sont extirpées du corps. Ils décharnent les os qu'ils font sécher au soleil et les remettent ensuite dans la peau. Lorsque les os sont bien placés dans la peau, ils remplissent le tout avec du sable fin et recousent le corps du défunt. Ils exposent ensuite ce corps dans un endroit approprié où l'idole Kiwasa sert de protection symbolique et où un Prêtre s'occupe jour et nuit du feu dans le but de conserver une température constante dans la pièce et de chasser l'humidité.

Planche tirée de
Moeurs des sauvages ameriquains,
comparées aux moeurs des premiers temps,
tome second, Paris, Père Lafitau, 1724
(P. Soulard, Musée du séminaire de Québec)

Lafitau, qui est venu en contrées «amériquaines» au début du XVIII[e] siècle, a recueilli maintes données sur ces peuples.

Ici on a un exemplaire de l'édition originale de son livre où on peut voir illustré le même tombeau que nous venons de voir en Virginie.

Il faut se rappeler qu'à cette époque, l'éditeur des livres donnait à un graveur le devoir d'illustrer les récits de voyages. Ainsi, le graveur, demeuré anonyme a dû s'inspirer aux mêmes sources que Picart. Le tombeau des rois est le même, à la différence qu'un roi mort semble attendre son traitement sépulcral. A l'avant-plan, des femmes et des hommes, dansent joyeusement, à la manière du *Convoi funèbre des Peuples du Canada* de Picart.

Bernard Picart (1673–1733)
Sacrifice que les Floridiens font au Soleil,
de leurs Permiers nez
Offrande que les Floridiens font d'un Cerf au Soleil
(Fig. 3, P. Soulard, Musée du séminaire de Québec)

Le soleil étant considéré comme une divinité par les Floridiens, les cultes qu'ils lui vouent sont nombreux. Dans le livre des abbés Banier et Mascrier les sacrifices du premier né et du cerf sont racontés de la façon suivante:

«Quelques Peuples de la Floride sacrifient leurs premiers nés au Soleil, ou plutôt à leurs Souverains. Du moins il est certain, que cette cruelle cérémonie se fait en présence d'un de ces Princes (. . .), qu'ils appellent Paraoustis. Pendant que la mère du petit enfant se couvre la face, pleure et gémit devant le bloc sur lequel la victime doit être écrasée, & que les femmes qui l'ont accompagnée, chantent et dansent en faisant un cercle, une autre femme paroit au milieu du cercle, tenant l'enfant entre ses bras, & le montrant au Paraousti. Cette femme danse comme ses compagnes, & chante en dansant les louanges du Paraousti. Après cela le Prêtre qui paraît dans le lointain de la Planche au milieu de six autres Floridiens vient écraser cet enfant. La victime doit toujours être un garçon».

«Ces mêmes Peuples offrent avec beaucoup de cérémonie la représentation d'un Cerf au Soleil. Ils choisissent pour cet effet la peau du plus grand Cerf qu'ils puissent trouver. Après l'avoir remplie de toutes sortes d'herbes, ils l'ornent de fleurs & de fruits, & l'élèvent au sommet d'un grand arbre, la tête tournée au Soleil levant. Cette cérémonie se fait tous les ans vers la fin du mois de Février & est toujours accompagnée de prières & de chansons, (. . .). Les Floridiens demandent au Soleil qu'il lui plaise de bénir les fruits de la tere, & de lui conserver la fécondité. Pour la peau du Cerf, elle reste exposée sur l'arbre jusqu'à l'année suivante. Les Grecs & les Romains offroient aussi quelquefois à leurs Dieux, au lieu de victimes véritables leurs représentations, sur tout à la place de victimes humaines».

Musée du Séminaire de Québec
Case postale 460 Haute-Ville
Québec G1R 4R7

No P 986.7 R 162G

Auteur PICART, Bernard (France 1673-1733)

Titre 1- SACRIFICE que les FLORIDIENS font au SOLEIL pour leurs PREMIERS nez
2- OFFRANDE que les FLORIDIENS font d'un CERF au SOLEIL

Signé, daté 1721

Dimension H. 37,6 cm L. 24,1 cm

Description Gravure au burin

Photographe Pierre Soulard **date** Mai 1986

Une permission écrite du Musée est requise pour fin de publication. L'oeuvre doit être reproduite en entier, à moins qu'une permission spéciale n'ait été obtenue. La mention PHOTOGRAPHIE MUSEE DU SEMINAIRE DE QUEBEC ET LE NOM DU PHOTOGRAPHE doivent accompagner la reproduction.

SACRIFICE que les FLORIDIENS font au SOLEIL, de leurs PREMIERS nez.

OFRANDE que les FLORIDIENS font d'un CERF au SOLEIL.

Figure 3.

Bernard Picart (1673–1733)
Maniere d'ensevelir les rois, et prêtres de la Floride

En arrière-plan, nous pouvons observer que lorsque les prêtres floridiens meurent, leur maison et effets personnels sont aussitôt brûlés.

Pour ce qui est des rois floridiens, ils sont enterrés et ce qui nous intéresse particulièrement ici c'est la présence du coquillage sur la tombe d'un roi. La conque symbolise la fécondité; sa forme, et sa profondeur rappellent l'organe sexuel féminin. Cette conque, sise sur un monticule de terre — le tombeau du roi — qui ressemble à un ventre de femme enceinte, préside à la renaissance. Les flèches plantées tout autour de la tombe représentent l'organe sexuel masculin, le phallus. Un lien est ainsi créé entre la vie et la mort, entre les symboles de la féminité et ceux de la masculinité.

Nous retrouverons cette même symbolisation reliée à la mort sur une autre gravure, illustrant un rituel funéraire floridien.

Gysbrecht Van Veen (1562–1628)
Prestigiator
Anonyme
Primogeniti solennibus ceremonijs Regi sacrificantur
Planches tirées des livres de Théodore de Bry
Americae Pars Prima
Americae Pars Secunda

Théodore De Bry, graveur et éditeur de livre, à la fin du XVI[e] siècle, inspira pendant plus d'un siècle toute une génération d'artistes peignant, dessinant, gravant les peuples exotiques. Gravant des dessins d'accompagnateurs d'explorateurs (John White et Jacques Lemoyne de Morgues), de Bry fait passer l'Amérindien par le moule de la beauté classique et uniformise la représentation des Amérindiens faite par White et Lemoyne.

Dans la gravure, *Prestigiator*, peu de différences sont identifiables entre la planche du livre de Bry et la gravure *Prêtre de la Virginie* de Picart. Mais dans cette autre gravure *Primogeniti solennibus ceremonijs Regi sacrificantur*, le traitement différent est aisément identifiable. En effet, contrairement à Picart, le graveur a mis la population amérindienne en présence de l'explorateur René de Laudonnière. Le chef indien, illustré en bon sauvage, tient l'explorateur par l'épaule lui expliquant «mélancoliquement» le rituel d'offrande d'un enfant mâle en l'honneur de son entrée en fonction de chef. Les accompagnateurs de l'explorateur regardent les floridiens comme des objets de curiosité.

Bernard Picart (1673–1733)
Cérémonie, observée par un des rois de la Floride,
avant que de faire une Expédition.
Un des rois de la Floride, consultant son magicien,
avant que de marcher à l'Ennemi

Les abbés Banier et Mascrier rapportent qu'avant chaque expédition de guerre le magicien adresse au soleil un culte bien spécifique. En effet, il le conjure de lui être favorable ainsi qu'à ses guerriers. Ensuite, le magicien entre en transe c'est-à-dire en communication avec les esprits et déclare à son roi «le nombre de ses ennemis, la manière dont ils sont campés, et le succès de l'expédition.»

Bernard Picart (1673–1733)
Floridiennes, qui ayant perdu leurs maris,
à la guerre, viennent implorer l'assistance du Roy.
Hermafrodites, destiné à servir les malades,
et à enterrer les morts. Veuves de la Floride,
qui sement leurs cheveux sur les Tombeux de leurs Maris

Les femmes des guerriers morts à la guerre implorent, selon les auteurs Banier et Mascrier, leur roi, de les venger. Pour marquer leur état de veuvage elles se font couper les cheveux à la hauteur des oreilles et ne pourront reprendre un autre amant qu'au moment où leurs cheveux auront atteint le niveau des épaules.

Les hermaphrodites, personnages bien à l'écart du groupe social, quant à eux, sont chargés de transporter malades et morts.

LES RARETÉS DES INDES

"CODEX CANADIENSIS"

ALBUM MANUSCRIT DE LA FIN DU XVII[e] SIÈCLE
CONTENANT 180 DESSINS

CONCERNANT LES INDIGÈNES, LEURS COUTUMES, TATOUAGES, LA FAUNE ET LA FLORE DE LA *NOUVELLE FRANCE*, PLUS DEUX CARTES.
REPRODUIT INTÉGRALEMENT, EN FAC-SIMILÉ
PAR LE PROCÉDÉ D'HÉLIOTYPIE
LÉON MAROTTE

PRÉCÉDÉ D'UN AVANT-PROPOS
PAR LE
BARON MARC DE VILLIERS

PARIS
LIBRAIRIE MAURICE CHAMONAL
20 ET 22, RUE DE VARENNE
1930

Figure 4a.

Figure 4b.

Louis Nicolas (1634?–1682?)
Les Raretés des Indes, Codex Canadiensis
(Fig. 4a,b)

Venu en Nouvelle-France de 1664 à 1675, le Père missionnaire jésuite Louis Nicolas nous a laissé par ce livre des documents ethnographiques très prisés par les chercheurs contemporains. Empruntant les contours des personnages illustrés avant lui par François du Creux dans *Historiae Canadensis*, Louis Nicolas dessine l'amérindien de manière naïve. Contrairement à Picart, il tribalise les personnages qu'il dessine; mais aussi influencé par son imaginaire d'européen, il drapera, quelques fois, à l'antique les chefs indiens. L'originalité de son oeuvre réside dans le fait qu'un texte accompagne les planches dessinées, texte démontrant la véracité de ses dires. Il révèle avoir vu devant lui ce qu'il décrit.

Malgré un dessin plus près de la réalité, malgré aussi que des textes accompagnent ces dessins, textes attestant sa venue, une représentation de faune bien particulière nous laisse penser que l'imaginaire de Louis Nicolas, ou du moins son imagination, était fortement marqué. Les monstres marins à queue de poisson et à corps de femme, une licorne aussi, qu'il dit avoir vue, sont dessinés.

DESIGN SYSTEM OF MOCCASIN ORNAMENTATION OF JANVIER BAND CHIPEWYAN

Cecile M. Clayton

Clothing and Textiles Department, University of Manitoba, Winnipeg, Manitoba R3T 2N2

Level: Master's

Abstract

Moccasin production and ornamentation continues to be an important cultural expression for many Chipewyan women of the Janvier Reserve at Chard in northern Alberta. The purpose of this research was to document the present day design system of moccasin ornamentation of this boreal forest Chipewyan settlement. A comparison of stylistic changes in moccasin ornamentation could then be made using museum samples from pre World War II.

While moccasins are still worn by some members of the community, most footwear is purchased commercially. Moccasin production and ornamentation is presently in a state of change from meeting a functional need to that of being one symbolic expression of Chipewyan culture, as well as a means of commerce for the women. For this reason, this study is important at this time.

Based on archival and museum research, traditional elements of Chipewyan ornamentation were identified. These elements included the use of quill, hair, floss, and bead embellishment applied in one of six motif categories. At Janvier,

the moccasin construction methods, beginning with skin preparation and including bead ornamentation, were documented over a three week period in May/June of 1986. Preliminary findings indicate a community style rather than a larger based 'group' style. Seed beads and moosehide are the predominant materials used for moccasin production and ornamentation in this community.

Key words: Chipewyan, Janvier, chard, design system, moosehide, moccasin ornamentation, beads.

Résumé

La confection et l'ornementation des mocassins constituent encore une importante activité culturelle pour de nombreuses femmes chipewyanes de la Réserve Janvier, à Chard dans le Nord albertain. L'auteure a cherché à illustrer les formes actuelles des motifs des mocassins dans cette Réserve chipewyane de la forêt boréale. On pourrait ainsi les comparer avec les objets muséologiques correspondants datant d'avant la Seconde guerre mondiale, afin de mettre en évidence leur évolution stylistique.

Bien que les mocassins soient encore portés par certains membres de la Bande, la plupart des chaussures sont achetées dans le commerce. La confection et l'ornementation des mocassins passent par une période de transition, car ils répondent de moins en moins à des besoins fonctionnels, mais expriment symboliquement de plus en plus la culture chipewyane, et leur confection constitue une source de revenu pour les femmes. C'est pourquoi la présente étude est d'actualité.

En se fondant sur des recherches effectuées dans les archives et les musées, l'auteure met en évidence les éléments traditionnels de l'ornementation chipewyane. Celle-ci se fonde sur l'utilisation des piquants de porc-épic, du crin, des graines séchées ou des perles de verre, et de fil de coton mercerisé, pour former des ornements de verroterie d'une catégorie de motifs parmi les six relevés. Les méthodes de confection des mocassins, de la préparation des peaux à l'application des ornements de verroterie ont été étudié par l'auteure au cours d'une période de trois semaines passées en mai-juin 1986 à la Réserve Janvier. Les conclusions préliminaires de l'étude sont qu'il existe un style local plutôt qu'un style de «groupe» plus largement répandu. Les principaux matériaux utilisés dans la confection des mocassins de cette localité chipewyane sont les graines séchées et la peau d'orignal.

Mots-clés: Chipewyan, Janvier, Chard, motif d'ornementation, peau d'orignal, ornementation des mocassins, perles, graines séchées.

Introduction

Moccasin production and ornamentation continues to be an important cultural expression for many Chipewyan women of the Janvier Reserve in northern Alberta. In the past, Chipewyan women used moccasin gifts as indicators of caring. Today, they continue to make special moccasins in honour of certain people such as family members, important visitors to the community, or as gestures of their regard for those who have contributed to the life of the community.

The purpose of this research was to document the present day design system of moccasin ornamentation of this boreal forest Chipewyan settlement. A comparison of stylistic changes in moccasin ornamentation could then be made using museum samples from pre-World War two.

While moccasins are still worn by some members of the community, most footwear is 'store bought'. Moccasin production and ornamentation is presently in a state of change; from meeting a functional need to that of being a symbolic expression of Chipewyan culture and a means of commerce for the women. This study is timely for the above reason as well as the fact that Janvier will in the near future no longer be an isolated community. Up to the present time, access to the community has been by train or air in the summer months, with the addition of a winter road to Fort McMurray. At this time, a road which will provide year round access is in the process of completion. The increased accessibility to the Reserve may influence changes in the traditional aspects of moccasin ornamentation which exist at the present time.

The Janvier Reserve is located at Chard, Alberta, approximately 290 kilometers northeast of Edmonton (Figure 1). The population on the reserve consists of 250 Chipewyan Treaty members, with an equal number of Cree and Metis residing in the surrounding area. The reserve was named for the four original families who were enrolled as residents of the area in 1900 under Treaty 8.

Around 1909, some of the members moved to the Portage La Loche area in northern Saskatchewan. From that day to this, a close relationship between the communities at Janvier, Garson Lake, and La Loche exists. Many of the women at Janvier had at one time resided in one of the other communities and still retained close kinship ties with family members there. They stressed the fact that there was no difference in the construction and ornamentation of moccasins from the three communities. In some instances a woman from one area might prepare the hide and cut the pattern pieces which a woman from one of the other communities would then ornament. Moccasins studied from the three areas were indistinguishable. Thus, for these reasons, samples from all three areas, as observed at Janvier, were included in this study.

Today, moccasin production and ornamentation in Janvier is carried out on an individual basis, or in association with an arts and crafts co-operative. Co-operation amongst the women, in all aspects of moccasin manufacture from skin preparation to ornamentation, is evident. Skin preparation is a lengthy and demanding skill which is often shared by two women who will then divide the end product in some mutually agreeable manner. In other instances, one woman might ornament the individual pattern pieces while a second woman completes the construction.

The name of the women's arts and crafts co-operative at Janvier is Chipewyan Prairie Products. The co-operative was initiated by some of the local women to encourage pride and continuation of cultural expression, to provide a productive activity for the women outside of the home, and to supply them with a means of commerce. Participation has varied over the six years since it was begun. At the time of the researcher's presence in the community, only a few women

Figure 1. Map of northern Alberta and Saskatchewan

were actually working at the designated meeting place, while others worked at home but marketed through the co-operative. Other women prefer to produce and sell moccasins independently. The numbers of women involved in either course are variable, ranging from two to twenty.

Research methods

Within the context of this study, design system refers to the motifs, materials, and methods of application utilized in moccasin ornamentation.

Based on archival and museum research, traditional elements of Chipewyan moccasin ornamentation were identified. These elements included the use of quill, hair, floss and bead embellishment. Six motif categories were identified by the researcher based on Duncan's (1982. 520) designated terms for Athapaskan clothing decorative imagery. These categories consisted of complex floral, simple floral, complex geometric, simple geometric, curvilinear abstract, or figural motifs. At Janvier, moccasin construction methods, beginning with skin preparation, and including bead ornamentation, were documented through sketches, photographs, and data collection sheets, from 12 May to 5 June 1986. These data were collected by visiting individual women working in their homes, by visiting the arts and crafts co-operative, and by recording relevant information on moccasins worn by members of the community in the course of daily activity.

The sample for this analysis consisted of thirty-four ornamented moccasins or moccasin pieces. In all examples, the material used for the main body construction was commercial or home tanned moosehide.

Findings

1. Moccasin Styles (Methods of construction)

Three moccasin styles were observed. The first style (style A), consisted of a wrapped cuff, t-shaped heel, rounded toe and crimped vamp. The cuffs were unornamented. Figure 2 is an example of this type.

A second style of moccasin was the slipper moccasin (type B). This style had a t-shaped heel, rounded toe, and crimped vamp. It had a fur or hide cuff which either completely surrounded the ankle opening, or only went from vamp edge to vamp edge. The cuffs were approximately 3 cm wide. Figures 3 and 4 are examples of this type.

Figure 2. Type A Moccasin

Figure 3.

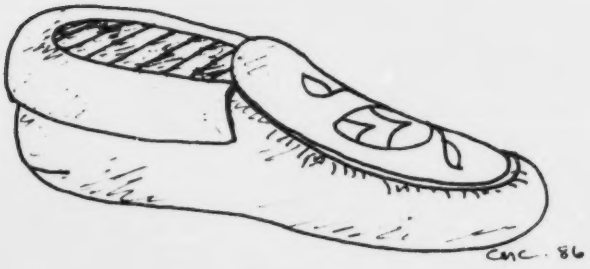


Figure 4.

Type B Moccasins

Type C, the third style of moccasin was a variation of the slipper and wrapped cuff type moccasin. They also had a t-shaped heel, rounded toe and crimped vamp, but were characterized by a deep stand-up cuff connected in front by short hide thongs, or an elastic behind the upper edge of the vamp. The cuffs were usually lined with cotton or cotton blend fabric on the inside, and heavily beaded on the exterior. Adult cuffs were approximately 8 cm deep, while children's cuffs were 5 cm deep. This style of moccasin was the most frequently observed type worn by the residents themselves. Figure 5 is an example.

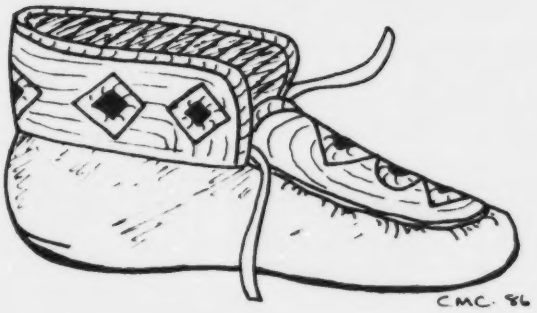


Figure 5. Type C Moccasin

A similar style, with Plains Cree attribution as well as examples of this type of moccasin made by Cold Lake Alberta Chipewyan in the late nineteen-fifties and sixties can be seen at the Glenbow Museum in Calgary.

All three styles of moccasins are hand-sewn using heavy cotton thread or commercial sinew. Essentially the three types have a similarly constructed base with differences occurring in the ankle treatment.

2. Motifs

The women of Janvier did not recall the use of symbolic motifs within their own or their mother's lifetimes. Three factors appeared to determine the choice of motif. First, moccasins might be ornamented with a special motif which had been requested by the person for whom they were being made. Second, the length of time which a woman had to make and ornament the footwear often determined the extent and complexity of the embellishment. Simple geometric forms take less time to work than floral or figural motifs. The third factor in motif choice was personal preference for a particular image. Artistic expression is apparent in these personal choices and had considerable importance as a decisive factor. Both traditional floral and modern abstract imagery is used. One woman enjoyed conveying the image of the local flora. Her motifs are easily recognizable as wild roses, strawberry leaves and the like. Another woman who is a recent artisan has developed a curvilinear abstract design based on a traditional rosebud floral image. This motif and variations of it, have been adopted by other women within the community. Figure 6 is one such motif.

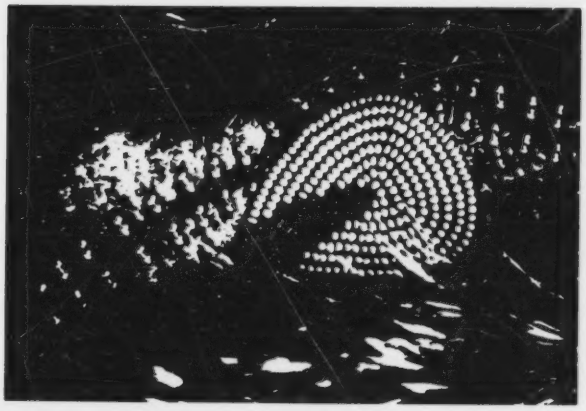


Figure 6. Abstract Curvilinear Rosebud/Pearl Drop Motif

The thirty-four moccasins documented were classified in one of the six motif categories. No other motif categories were observed. Figure 7 indicates the numbers within each category.

Figure 7. Number in each category

Complex Geometric	11
Simple Geometric	6
Complex Floral	7
Simple Floral	6
Abstract Curvilinear	4
Figural	0

Appendix A lists the motifs observed at Janvier and shows their characteristics.

Type A and type B moccasins were ornamented on the vamp area only. Type C moccasins were ornamented on both the cuff and vamp area. There were no exceptions to this observation.

3. Materials

The women at Janvier use seed beads for moccasin ornamentation. The beads are two to three millimeters in circumference, smooth, and of a circular shape. Apart from seed beads, the only other decorative material used were sequins. These were seen in two examples documented at Janvier.

4. Color

Fourteen colors of varying hues were observed. Shades of blue occurred most frequently, followed by green, red, orange, pink, yellow and white, in order of frequency of usage. White was the most frequent background color for the heavily beaded type C dress moccasins.

Out of the thirty-four moccasins observed, twelve included the complementary color combinations of blue/orange, nine of red/green, and two of yellow/purple tones. None of the women had received formal art training. The color choices were due to subjective preferences rather than theoretical art considerations.

As well as the difference in size between men and women's moccasins, some informants stated that color could be used as a differentiation factor. Pink was the only color mentioned in this regard. It was felt by some women to not be suitable for men's or boy's moccasins.

Methods of Application

Separate moccasin pieces are ornamented prior to construction of the whole. The procedure followed in moccasin ornamentation by the women at Janvier is documented below.

Step one: Motifs are drawn on the hide using a ball point pen.

Step two: Some of the women sew a piece of brown paper on the underside of the hide piece to be decorated because they find that it provides a stiffer fabric to work on resulting in a smoother beaded design surface. Figure 8.

Step three: Using a small eye long needle and cotton thread double threaded for strength, seed beads are picked up on the needle in the order that they are positioned in the motif.

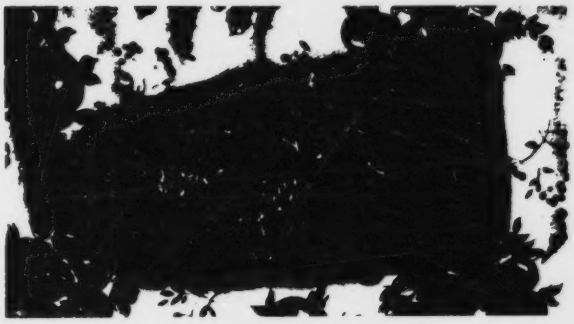


Figure 8. Step Two

The number of beads picked up at one time varies but is generally around six. The beads are then pushed along the thread to the hide and set along the motif contour line. Figure 9.

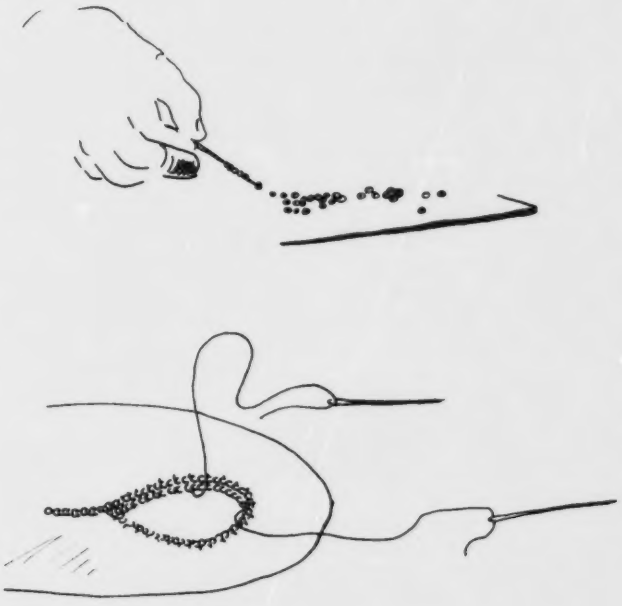


Figure 9. Step Three

Step four: A second needle and thread, knotted on the underside of the hide is used to spot stitch or 'couch' the thread holding one or two beads to the hide and through paper if this is used. Stitching the beads at intervals of one or two beads ensures a secure attachment to the hide and allows for greater flexibility in the motif design. Figure 10.

Step five: To obtain a symmetrical motif on both pieces, the beaded contour piece is placed beaded side down over the other piece and pressed with a moderately hot iron for a few minutes until an impression is made in the second piece. This piece is then worked in the same manner as the first one.

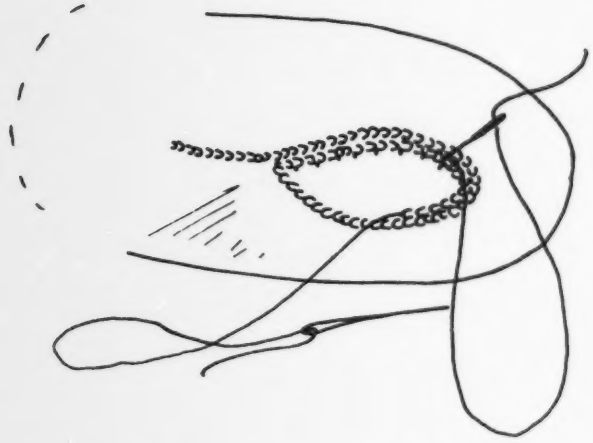


Figure 10. Step Four

If a motif has a 'filled in' beaded design, it is always worked from the outside of the contour line towards the center of the motif following the contour line in diminishing rows of beads.

Step six: When the motif is completed, the paper on the underside is cut around the stitches which encompass the motif and the underside is then lined with cotton or a cotton blend fabric using an overcast stitch with the lining edge folded under. This decreases seam bulk on the finished moccasin. Figure 11.

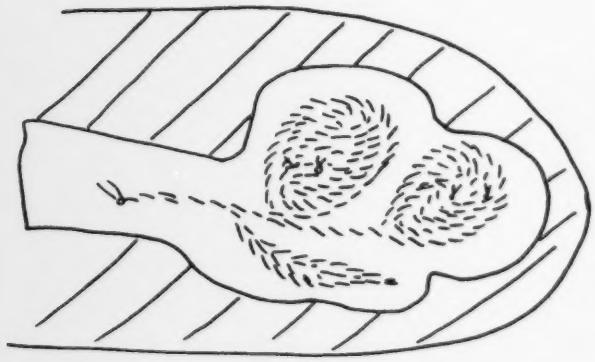


Figure 11. Step Six

Step seven: The moccasin pattern pieces are then sewn together by hand using a glover needle and commercial sinew. Glover needles are very sharp square nosed needles suitable for hide penetration.

If the moccasins being ornamented are type C, an additional ornamentation technique is often employed on the cuff edge. The edges are treated in one of three ways. They can have a single row of beading couched after every bead or every other bead as shown in Figure 12. The moccasins can have a 'corded' bead edge as shown in Figure 13. They can also have a 'scalloped' bead edge as illustrated in Figure 14.

Figure 12. Single Row Edging

Figure 13. 'Corded' Edging

Figure 14. 'Scalloped' Edging

The scalloped bead edge as employed at Janvier is a variation of the edging referred to by Duncan (1982.517) as 'zipper outer', and by Orchard (1929.160) as 'two bead edging'. The difference as observed in the moccasins at Janvier is in the number of beads used. The moccasins in this sample were made in a 3:1 ratio (3 horizontal:1 vertical), whereas Duncan refers to a 1:1 ratio, and Orchard to a 2:1 or 2:2 ratio. Orchard states that this type of edging is ". . . an almost universal type" (Orchard, 1929.160).

Conclusion

The women of the Janvier Reserve are very receptive to changes in the design system of moccasin ornamentation. While it is their intention to preserve traditional elements such as the use of sinew and home tanned moosehide in the manufacture of moccasins, there does not appear to be any adamant opinion regarding traditional Chipewyan motifs or methods of ornamentation. As noted earlier in this paper, motif choice is based on three factors, none of which include the concept of specific Chipewyan symbolism or tradition.

Ornamented moccasins continue to be used by these women as gestures of respect or affection. Special moccasins were made to present to the Pope on his recent visit to Canada, as well as for the parish priest who transferred to another community, and for members of their families.

The differences between men's and women's moccasins are insignificant. Apart from the expected difference in size, color choice was the only other possible distinguishing feature. According to some of the women, pink is rarely used on male moccasins, but this was not rigidly adhered to.

At this time the researcher is not in a position to identify possible influences from other communities on the design system of moccasin ornamentation from the Janvier Reserve. To date there has been little focus on this cultural component of the Chipewyan people as a whole. The

researcher intends to carry out a further similar study of a more traditionally located 'caribou eater' Chipewyan community, as well as determine the changes which have occurred since pre World War II.

Change in northern communities continues to accelerate and the cultural heritage of this group is in danger of becoming too obscure for their own historical records, as well as for the broader Canadian perspective.

References

Birket-Smith, K. (1930). Contributions to Chipewyan ethnology. Report of the Fifth Thule expedition 1921-1924. Copenhagen: Glydendalske Boghandel, Nordisk Forlag.

Boudreau, J. (Ed.), (1974). Athapaskans, strangers of the North. Ottawa: National Museums of Canada.

Brandson, L.E. (1981). From tundra to forest, a Chipewyan resource manual. Winnipeg: Manitoba Museum of Man and Nature.

Duncan, K. (1982). Bead embroidery of the Northern Athapaskans. Unpublished doctoral dissertation, University of Washington, Seattle.

Gillespie, B. (1971). Territorial expansion of the Chipewyan in the eighteenth century. National Museum of Man Mercury Series Ethnology, paper 11, 350-388 (27).

Hatt, G. (1916). Moccasins and their relation to Arctic footwear. Memoirs American Anthropological Association. 3, 149-250.

Helm, J. (Ed.), (1981). Handbook of North American Indian. 6 (Subarctic). Washington: Smithsonian Institution.

Orchard, W. (1975). Beads and beadwork of the American Indians. New York: Museum of the American Indian Heye Foundation.

Wissler, C. (1919). Indian beadwork. New York: American Museum Press.

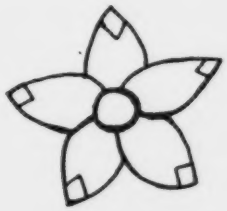
Appendix A

Motifs observed on Janvier moccasins

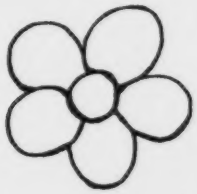
Floral:

1. *Rosettes*: Duncan identifies these as ". . . frontal blossom form, all petals congruent. . ." (Duncan 1982.538).

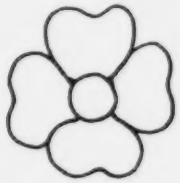
   a.) point petalled with center.



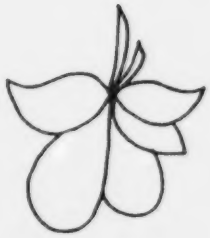
   b.) round petalled with center.



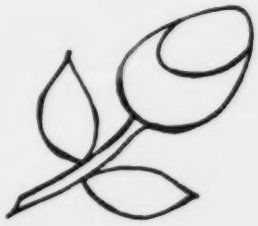
   c.) dipped petals with center.



2. *Berry*:



3. *Rosebud*: Profile of a rosebud form with stems and leaves in varying relationships.



Curvilinear abstract: Abstract image of a rosebud and/or pearl drop.

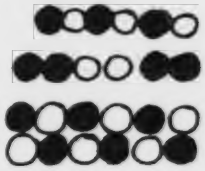
Geometric:

1. *Interrupted lines*:

   a.) single color.

   b.) two colors.

   c.) two rows/two colors.

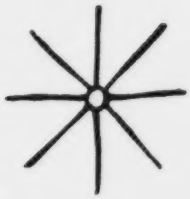


Appendix A — continued

d.) three rows/two colors.

e.) four rows/two colors.

2. *Stylized Star*:



3. *Zigzag*:
   a.) one row.
   b.) several rows.

a.) b.)

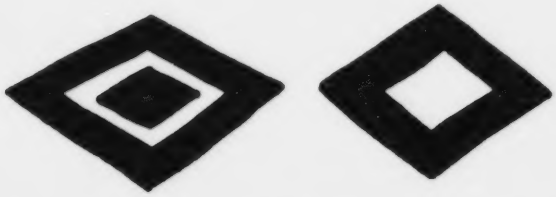
4. *Chevrons*:

5. *Circles*:

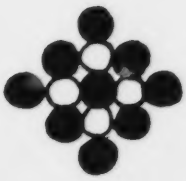
6. *Triangles*:

7. *Crosses*:

8. *Diamonds*:
   a.) two bead filled in contour outline.
   b.) diamond within a diamond.



b. a.



c.

c.) multicolor filler.

DRUM-DANCE MUSIC OF THE INUIT OF NORTHERN BAFFIN ISLAND: AN ANALYSIS OF ONE SONG AND ITS VARIANTS

Paula Conlon

Faculté de la musique, Université de Montréal, Montréal, Québec H3C 3J7

Level: Ph.D.

Abstract

Until now, no detailed study has been undertaken of the music of the Inuit of northern Baffin Island. In 1985 I collected material from Arctic Bay. These, together with songs collected by Jean-Jacques Nattiez from Pond Inlet and Igloolik in 1976 and 1977, amount to approximately 300 songs.

I have chosen one song and its variants to analyze in this paper. Eleven versions of the song were collected. A paradigmatic approach has been used to demonstrate the similarities and differences between versions. Each line encompasses the overall tune. Capital letters are used to delineate phrases and phrase variations. These phrases are then broken down into subphrases shown by small letters.

My thesis will be a semiological analysis of the entire corpus of songs recorded. The aim is to determine classification systems and compositional tendencies within the cultural context. It is hoped that the preservation of these songs will be of use to future generations, both Inuit and white, in studying traditional Inuit culture.

Key words: Drum Dance songs.

Résumé

Jusqu'à présent, on n'avait entrepris aucune étude détaillée de la musique des Inuit du Nord de l'île de Baffin. En 1985 et 1986, l'auteur a recueilli des chants dansés à Arctic Bay, lesquels, ajoutés aux chants recueillis par d'autres à Pond Inlet et à Igloolik en 1976 et 1977, font un total d'environ 300 chants dansés avec accompagnement.

L'instrument de beaucoup le plus utilisé est le tambour, fait de peau de caribou tendue sur un cadre circulaire en bois, dont on frappe le pourtour avec une batte en bois. La plupart des chants dansés au tambour ont pour thème la vie quotidienne, et les concours de chants dansés permettent aux gens d'exprimer ce qu'ils pensent. Ces chants très personnels sont généralement composés par un homme dans un lieu solitaire, puis enseignés à sa femme qui à son tour les diffuse parmi les autres femmes. La danse au tambour constitue ainsi un facteur de cohésion de la collectivité inuit.

Mots-clés: Chants dansés au tambour.

Introduction

Until now, no detailed study has been undertaken of the music of the Inuit of northern Baffin Island. In 1985 I collected material from Arctic Bay. These, together with songs collected by Jean-Jacques Nattiez from Pond Inlet and Igloolik in 1976 and 1977, amount to approximately 300 songs (see map, Figure 1).

> [A] type of traditional music, known as pisiit, tells of things that have happened in the past. . . . Pisiit are now being sung by anyone, whereas before, the composer, his namesake or one of his relatives would be the only ones to sing a specific song. Today anyone can sing another person's pisiq (Owingayak, David 1983: 11).

"Ayaya" means "to sing" in the sense of singing an "ayaya" song. "Ayaya" is now used interchangeably with the older song term "pisiq". Noah Urunaaluk stated that:

> The way these ayayas were made, maybe when this man went out hunting alone, in his own little iglu, he'd get up, get ready for bed, and start making songs himself. Whenever he went away, he'd sing the same songs, until he knew all the words by heart (Pond Inlet 1977: interview).

The text of the song is the most important element. Donald Suluk, a drum dancer from Eskimo Point (west coast of Hudson Bay), expresses this concept:

> When we older people hear modern English music on the radio, we find it very repulsive. When you don't understand what they are saying, you don't even want to listen. In the Inuit way of listening to songs, you don't really listen to the tune but to what is being said. . . . The song has to be sung completely and followed according to how it's composed. But if it was to be sung, say, with some words missing or with the verses mixed up, it could insult the song's writer or family members. . . . If it is sung properly, it can be a source of happiness (1983: 28).

Since the language is polysynthetic (expresses whole thoughts by one word) much power and beauty is lost in translation. Also, events are often hinted at, appearing clear to kinsmen, not to outsiders. For this reason the story behind the song was requested, although the singer did not always know its meaning.

Song #1 and its variants: Introduction

I have chosen one song that is especially popular to analyze in this paper. Eleven versions of it were collected from Arctic Bay and Pond Inlet. (The omission of this song from the Igloolik corpus suggests that it was only known locally). This song is ascribed to the singer Qargiuq:

> One winter, he was really sick, with TB, and he thought he was going to die before spring. And he got better again, and when he was hunting seal, in spring time, he said, 'I'm so glad I'm gonna live, to see the spring come again' (Qango, Pond Inlet 1977: interview).

Figure 1. Map of Baffin Island area.

The following texts show the variations between versions while still retaining the overall meaning:

I'm so happy I'm going to be alive
The sun has appeared, the day is coming (#1,2,3,4)

It's a happy time because I'm going to live
The sun has caught up, the day is still ahead (#5)

It's a happy time now, the day is still ahead
It's a happy time, the sun is thawing out
I'm going to live now, the day is still ahead (#6)

The sun has caught up
I'm going to experience the beautiful spring season
The day is still coming (#7)

The sun has appeared so the day is coming
Let me breathe because I'll be living (#8)

Let me put on my oxygen mask,
I'm going to live now
The sun has appeared, the day is still ahead
It's a happy time, I'm going to live now (#9)

Let me put on my oxygen mask because
I'm going to live
The sun has caught up, the day is still ahead
It's a happy time because I'm going to live (#10)

Text not understandable due to noise of drum (#11)

Inuit music is broadly defined as follows:

> Each song has a nuclear theme which identifies it and which is subject to modification, enlargement and fragmentation. Canadian Eskimo songs are generally pentatonic, with a verse-and-refrain structure and with scope for much rhythmic variation. They have a range of an octave or less; melodic contours are generally descending (Binnington, Ming-Yueh 1980: 320).

The verse-and-refrain structure is prevalent in the songs collected from northern Baffin Island. A descending line occurs in some sections of songs but is not all-pervasive. The

average range is an octave. Cavanagh comments on pentatonic scales with regard to the nearby Netsilik Inuit (to the west of Igloolik; see map Figure 1: Spence Bay, Gjoa Haven, Pelly Bay):

> The consistency of the tonal structure of the drum-dance songs is remarkable: 83% of the current repertoire is based on penta-type scales (1982: 106).

The use of the five-note scale in song #1 and its variants exemplifies this trend. Since the penta-type tonal classification does not contain semi-tones or tritones, it is not surprising to find an absence of these intervals in the song under study. The intervals used (in the average of song #1 and its variants) are: unisons (47.5%), ascending (8.6%) and descending (12.6%) major seconds, ascending (6.2%) and descending (17.3%) minor thirds, and ascending (6%) and descending (1.8%) perfect fourths.

The tonal centres have been determined by frequency of occurrence, taking duration of notes into account as well. "C" is the tonal centre of song #1 and its variants (32.6% of the average of all versions).

The following discussion of Netsilik drum-dance songs applies equally well to the song under study:

> A majority of the total number of melodic progressions in the songs are tone reiterations [unisons]. Of these, the largest proportion occurs on the tonal centre. Most of the reiterations on the tonal centre are in the chant portion of the songs where long series of tone reiterations serve to declaim the notes . . . Other pitches on which series of three or more tone reiterations occur are . . . the tones a perfect fourth and a major second above the tonal centre (Cavanagh 1982:122).

In song #1 and its variants, the many unisons on "C" strengthens this note as the tonal centre. As with the Netsilik, the tones a perfect fourth ("F") and a major second ("D") above the tonal centre have series of three or more tone reiterations.

Of the 11 versions of this song, songs #1–6 are versions whose initial A phrases begin the same way (i.e. subphrase a1). Songs #7–11 are versions which are more varied. A paradigmatic approach has been used to demonstrate the similarities and differences. The transcriptions are transposed to the same tonal centre for purposes of comparison. Each line encompasses the overall tune (1, 2 etc.). Capital letters (A, B etc.) are used to delineate phrases and phrase variations (A1, A2 etc.) These phrases are then broken down into subphrases shown by small letters (a1, a2 etc.). Variations of these subphrases are represented by decimal points after the number to show which subphrase they belong to (a1, a1.1; a2, a2.2 etc.). (This approach is derived from Nattiez 1975: *Fondements d'une sémiologie de la musique*).

This song shows consistency across versions found both within the same community and between Arctic Bay and Pond Inlet. A paradigmatic representation of the Song is shown in Table 1 (The musical transcription of the beginning of this song is shown in Figure 2).

Figure 2. Transcription of the beginning of song #1.

TABLE 1
Line 1 of song #1

1)											C			
														c3
2)			A				B				C1			
		a1		a2			b1		b2			c1	c2	c3.1
3)			A				B				C2			
												c1	c2.1	c3.1
4)			A				B1				C2			
								b1.1		b2.1				
5)			A1				B				C3			
		a1		a2.1								c1	c2.1	
6)			A				B				C2			
7)			A1				B2				C4			
								b1		b2.1		c1	c2	

A phrase

Eighth notes predominate A phrases (84.2% of the average of A phrases) and the total versions (69.8% of the average of all versions). The initial A phrase of songs #1–6 begins with two eighth notes, a syncopated figure of eighth note, quarter note, eighth note, and two eighth notes (a1). This figure, with variations, predominates the A phrases. Its variations include four eighth notes at the end of the a1 phrase (#3:A8:a1.4; #5:A12:a1.6, A13:a1.7; #6:A18:a1.11; #8:A22:a1.14, A23:a1.15), all eighth notes (#6:A18:a1.11; #7:A20:a1.12; #10:20:a1.12), starting with two eighth notes followed by a dotted eighth note and a sixteenth note (#9:A24:a1.16; #10:A27:a1.18), and a mixture of syncopated notes in various parts of the a1 phrase (#9:A26:a1.17; #11:A31:a1.22).

"D" is the tonal centre of the average of A phrases (46.5%), followed by "C" (27.5%). The overall tonal centre "C" (32.6% of the average of all versions) begins and ends the majority of A phrases. Exceptions are #5 (A12:a1.6, A13:a1.7, A14:a1.8) and #11 (A30:a1.21). (In these versions the a1 phrase begins on the "G" below "C" but otherwise conforms to the overall A pattern.)

The pitches and rhythm of the notes in a1 subphrases vary slightly. In the subphrase a2 the pitches remain relatively constant with minor variations in the rhythm. Each subsection (a1,a2) has roughly four beats (quarter note=one beat).

Unisons are most common in an average of A phrases (61%) as well as overall (47.5%). Except for the occasional ascending (.7%) and descending (3%) perfect fourth, the only other intervals used are ascending (15%) and descending (9.7%) major seconds, and ascending (7.1%) and descending (3.5%) minor thirds. This interval arrangement is consistent with Netsilik songs:

> the most frequent intervals created by melodic inflection were between a minor and major second . . . and a minor and major third (Cavanagh 1982: 110).

B phrase

Sachs notes that "the most fascinating of the oldest melody patterns may be described as a 'tumbling strain' " (1962: 51). The B phrase demonstrates the "forceful intonation of the highest notes and the subsequent flagging [weakening] on a melodic descent" (Sachs 1962: 55). The B phrase gradually descends, spanning the entire range of the song (i.e. G1 to G). The only exception to this is #4 (B11:b2.6, B7:b2.5). (These B phrases appear to be an amalgamation of B and C phrases. There is no C phrase following either of these B phrases and the reiteration of the pitch "C" at the end of the b2 subphrase is similar to the end of c2 subphrases. The C phrase follows the B phrase in the rest of the song and these B phrases conform to the gradually descending pattern.) In song #8 the singer begins the song with a fragment of the descending b2 subphrase (B19–:b2.12; the dash after B19– indicates that this phrase is shortened).

There are slight variations in pitch and rhythm between B phrases in different versions. Eighth notes predominate B phrases (59.5%), followed by quarter notes (39.3%). Subphrases b1 and b2 have approximately four quarter-note beats each. (In songs #1 and #2 the singer occasionally puts an emphasis on the fourth quarter-note beat which alters the dividing line between b1 and b2).

Unisons make up 38.7% of the average of B phrases, followed by descending major seconds (28.4%), descending minor thirds (21.3%), ascending major seconds (10%) and ascending perfect fourths (1.6%). The tonal centre of B phrases is "F" (24.3%).

Boas notes that "the chorus, amna aya, [is] the never failing end of each verse" (1964: 194). The B phrase is usually sung to the word "ayaya" (exceptions with text are song #7 (B17:b1.14), #9 (B21:b1.14) and #11 (B24:b1.15).

C phrase

"Ayaya" is the text for all the C phrases. I have divided the C phrase into c1 (first two quarter-note beats), c2 (remainder of phrase up to rest(s)), and c3 (reiteration in varied form of the end of c2 subphrase). The c1 sections remain constant throughout each individual song, the exceptions being occasional cut-off of the last note to insert a rest to breathe (#4: c1.2(C8,C11) and being omitted entirely (#6: C15–, C16–, C17–).

The main variations in the C phrases occur in the c2 subphrase, with use of different rhythm, pitches and number of beats. Although eighth notes predominate the C phrase (54.4%), followed by quarter notes (27.6%), the c2 subphrase ends with increasingly longer rhythmic values, generally finishing with a half note or longer. (Exceptions are subphrase c2.2 (#3:C5; #5:C12; #7:C19; #8:C12; #9:C12; #11:C12) which ends with a dotted quarter note followed by a rest to breathe; subphrase c2.12 (#8:C20) which ends on a quarter note "C" followed by a rest to breathe; subphrase c2.11 (#6:C17–) which ends with a quarter note "C" followed by an eighth note "C", and subphrase c2.13 (#10:C24) which ends with a quarter note.

The longer note values of C phrases highlight the "C" so that although "D" is the most frequent of the longer A phrase and "F" the most frequent of the longer B phrase, the "C" is still felt to be the tonal centre overall (32.6%). The C phrases are primarily an establishment of the tonal centre "C" (84.4% of an average of C phrases) with a dip down to the pitch "A" at the beginning of subphrase c2. The only exceptions to this are song #4 (C:c2.4) whose subphrase c2 begins on "C" (which I think is a modification of the individual singer), and song #6 (C15–:c2.9, C16–:c2.10, C17–:c2.11) which begins on "C". (In song #6 the "C" at the beginning of the c2 subphrase may be a retention of the missing c1 subphrase).

The C phrase generally ends on the tonal centre "C". Exceptions are subphrase c2.7 (#5:C13) which finishes with a perfect fourth leap down from "C" to "G", and subphrases c2.9 (#6:C15–) and c2.10 (#6:C16–) which finish with a minor third leap down from "C" to "A". C phrases that end with the downward leap are the end of the overall section as there is no c3 subphrase before the repetition of the A phrase.

The c3 subphrases have endings of a downward leap in most versions (a perfect fourth from "C" to "G" (#3:c3.2,c3.3), and a minor third from "C" to "A" (#7:c3.4; #10:c3.5,c3.6,c3.7; #11:c3.8,c3.9)). The only versions where the end of the c3 subphrase does not fall in pitch are #1(c3,c3.1) and #2(c3,c3.1), both sung by Koonoo Ipirq, and the end of #11(c3.10).

The designation of c3 is used when this small section is separated from the c2 subphrase by a rest(s). The c3 subphrases are found at the end of some overall phrases and not others. Occasionally they begin or end the song as well (begin: #1,2,7,10; end: #11).

Unisons make up 43.1% of an average of C phrases, followed by descending (41.9%) and ascending (13.5%) minor thirds. The frequent unisons on the pitch "C" strengthen its function as the tonal centre.

Variations with drum accompaniment

> Qilautit, or drums . . . are used exclusively for drum dances and pisiit. . . . What is important is that he doesn't desecrate the pisiit, or perform pisiit with guitar. . . . They should be accompanied only with the traditional drum (Owingayak, David 1983: 11).

The Inuit drum from the Baffin Island area is made of caribou skin stretched over a circular wooden frame; it is struck on the rim by a wooden beater. Traditionally the man who composes the song teaches it to his wife who in turn teaches the song to the other women in the village. At the drum dance the men take turns playing the drum while the women sing the drum dancer's songs.

The drummer occasionally interjects with a "yahoo" or similar sound but otherwise remains silent. (Pisiit sung by the drummer are also found but it is usually the wife who sings her husband's composition).

Drumming in Inuit music is broadly defined as follows:

> In the Canadian Eskimo groups there is frequently an apparent lack of synchronization of tempos and rhythm between the drumming and the singing, the drumming tending to vary in tempo several times during a song (Binnington, Ming-Yueh 1980: 320).

Songs #1 and #11 are accompanied by the drum. In song #11 the singer sings at a metronome marking of quarter note=92 while the drummer is at M.M. quarter note=120. When I asked about the lack of synchronization I was told that "traditionally the singer and drummer don't play exactly together" (Arreat, Lazarus; Arctic Bay, 1985: interview). (Both versions have the drummer interjecting with periodic yells (#1: "yahoo"; #11: "yehee")).

In song #1 the drummer keeps approximately the same beat as the singer (M.M. quarter note=116), only separating occasionally when the singer's rhythm fluctuates more than the drummer's. Song #1 is performed by a singer and drummer who perform together frequently and "go out to sing" (e.g. participate in the Spring Games held in Iqaluit (Frobisher Bay) each year). The drummer, David Kalluk, is a young man (born 1950) as compared to Qumangapik (#11) (born in 1905). Kalluk speaks English and has had a lot of contact with white music.

Conclusion

This study is a representative section of my doctoral thesis on *The Drum-Dance Songs of the Inuit of Northern Baffin Island* (Faculty of Music, University of Montreal). My thesis will be a semiological analysis of the entire corpus of songs (approximately 300) collected from Arctic Bay, Pond Inlet and Igloolik.

The aim of this research is to determine classification systems and compositional tendencies within the cultural context. A parallel objective is the collection of this material before it disappears. Traditionally the songs are passed down orally from one generation to the next. In recent times, however, the influence of white culture (e.g. rock and country music) has pervaded much of Inuit music. By collecting and transcribing the music of this area, it is hoped that the preservation of these songs will be of use to future generations, both Inuit and white, in studying traditional Inuit culture.

References

Arreat, Lazarus, 1985. Personal Interview. Arctic Bay.

Binnington, Doreen & Ming-Yueh, Liang, 1980. "North America: Eskimo." The New Grove Dictionary of Music and Musicians. 13:318–320. London: Macmillan Publishers Ltd.

Boas, Franz, 1964. The Central Eskimo. Originally published in 1888. Nebraska: University of Nebraska Press.

Cavanagh, Beverley, 1982. Music of the Netsilik Eskimo: A Study of Stability and Change. Vol. 1. Ottawa: National Museums of Canada.

Nattiez, Jean-Jacques, 1975. Fondements d'une sémiologie de la musique. Paris: Union Générale D'Éditions.

Owingayak, David, 1983. "Interview: David Owingayak." Inuktitut. 54:10–15, December.

Qango, 1977. Interview with Jean-Jacques Nattiez. Pond Inlet.

Sachs, Curt, 1962. The Wellsprings of Music. New York: Da Capo Press.

Suluk, Donald, 1983. "Some Thoughts on Traditional Inuit Music." Inuktitut. 54:24–30, December.

Uruunaluk, Noah, 1977. Interview with Jean-Jacques Nattiez. Pond Inlet.

LES FACTEURS SOCIO-CULTURELS ASSOCIÉS À L'ÉTIOLOGIE DE L'OTITE MOYENNE CHEZ LES ENFANTS INUIT DU NOUVEAU-QUÉBEC

Rose Dufour

Département d'anthropologie, Université Laval, Ste-Foy, Québec G1K 7P4

Niveau: Doctorat

Résumé

Jusqu'à maintenant toutes les recherches sur l'étiologie de l'otite moyenne ont été réalisées selon le modèle cartésien de la causalité qui inspire la démarche biomédicale. Après avoir identifié le paradoxe de ce modèle, l'auteure reformule complètement l'approche théorique de l'otite moyenne en tentant d'opérationaliser le modèle systémique. Cela signifie que l'otite moyenne n'est plus vue seulement comme le résultat de causes mais aussi comme un symptôme d'un système qui fonctionne.

Pour atteindre cet objectif, l'auteure se propose d'utiliser deux méthodologies qui sont deux niveaux de la même réalité. La première est appelée la construction de l'épidémiologie sociale et culturelle: construction comparative de l'otite et la seconde est appelée la construction culturelle: métaphores sur l'otite. C'est le couplage des deux systèmes, des deux méthodologies, qui devrait montrer comment se construit l'otite moyenne.

Mots-clés: Nouveau-Québec Inuit, otite moyenne, santé et maladie chez les Inuit, enfants inuit.

Abstract

All the research on the etiology of otitis media has so far been carried out in accordance with the Cartesian model of causality which underlies biomedical procedures. Having identified the paradox of this model, the author is now attempting to operationalize the systemic model with a view to completely reformulating the theoretical approach to otitis media. This means that otitis media is no longer seen merely as the result of causes, but also as a symptom of a functioning system.

The author proposes to achieve this goal by means of two methodologies which are two levels of the same reality. The first of these is termed the construction of the social and cultural epidemiology: comparative construction of otitis, and the second is called the cultural construction: metaphors about otitis. By coupling the two systems or methodologies together it should be possible to show how otitis media is constructed.

Key words: New Québec Inuit, otitis media, health and sickness among the Inuit, Inuit children.

Introduction

L'otite moyenne constitue l'un des plus sérieux problèmes de santé (McShane 1982) et l'une des maladies les plus fréquemment diagnostiquées pendant l'enfance (Bluestone *et al.* 1983; Jeliu et Forget 1983). Il semblerait que ce problème s'étend au moins à tout l'Occident. Le Nouveau-Québec n'échappe pas à ce profil, au contraire car les enfants inuit se distinguent par leur tendance marquée à développer, comme complication, une perforation tympanique à laquelle s'ajoute une suppuration chronique (Schaefer 1971, Baxter 1972) qui a pour effet à long terme, de produire une nécrose du tympan.

Cette otite moyenne chronique est un problème difficile pour lequel il n'existe *aucun* traitement médical et chirurgical efficace (Baxter dans Labbé et Moffat 1983:6). Elle suscite donc beaucoup d'inquiétude en raison des troubles auditifs qu'elle occasionne et d'où découlent des problèmes de développement du langage, de la parole et de l'apprentissage scolaire.

La prévalence de cette maladie est reconnue plus élevée chez certaines populations marginales du point de vue socio-économique et politique (Hudson et Rockett 1984:73) notamment chez les aborigènes australiens, les Inuit, les Indiens américains et les Maoris de la Nouvelle-Guinée. À cet égard, on ne peut que s'étonner des remarquables différences observées entre deux populations autochtones du Nouveau-Québec (les Inuit et les Cris), qui vivent dans les mêmes conditions climatiques, environnementales et économiques. En effet, les résulats d'un dépistage de la fréquence et de la gravité des troubles auditifs chez les enfants d'âge scolaire ont permis de mettre en lumière que 81% des enfants inuit examinés avaient une pathologie active de l'oreille alors que moins de 20% des enfants Cris tombaient dans cette catégorie et qu'au test audiologique, seulement 77% des enfants inuit avaient une audition bilatérale alors que chez les enfants Cris ce pourcentage s'élevait à 96 (Baxter *et al.* 1986, Julien *et al.* à paraître).

La médecine explique généralement les différences entre les populations en termes de concepts biologiques reliés à l'environnement. Ce modèle d'explication a montré ses limites puisqu'après vingt ans de recherche (McShane 1982) son épidémiologie est mal connue, son étiologie et sa pathogénie sont imparfaitement comprises, son diagnostic est difficile, son histoire naturelle est hautement variable et non prévisible et son traitement controversé (Meilleur et Mishra 1981:1).

Dans un premier temps je ferai le point sur l'état des connaissances médicales. J'expliquerai ensuite le paradoxe du modèle bio-médical pour reformuler l'approche théorique de l'otite moyenne en tenant compte de la culture et de l'histoire de la pratique médicale nordique dans un modèle que je qualifie pour l'instant de systémique. Recherche située aux frontières de la clinique, de l'épidémiologie et de l'anthropologie mais dont la pratique est exclusivement celle de l'anthropologie, les données cliniques et épidémiologiques permettant la précision et la délimitation de son application.

L'État des connaissances

L'otite moyenne: le dossier clinique et épidémiologique

Aux États-Unis, on a considéré que le sujet offrait suffisamment d'intérêt pour créer un Centre de recherche sur l'otite moyenne (Otitis Media Research Centre au Children's Hospital de Pittsburgh).

De prestigieux colloques ont eu lieu à Chicago en 1982 (Bluestone *et al.* 1983) et à Washington en 1984 (Bluestone *et al.* 1986), et ils regroupaient des experts en pédiatrie, en maladies infectieuses, en oto-rhino-laryngologie, en épidémiologie, en audiologie et en bio-statistique, qui constatent leur impuissance devant cette maladie. Pour ces chercheurs, les mêmes conclusions que Meilleur et Mishra (1981) s'imposent tant sur son épidémiologie (Biles *et al.* 1980), son étiologie (Harrison *et al.* 1985; Bodor *et al.* 1985; McShane 1982) et son traitement (Paradise 1986).

Concernant plus directement les populations inuit, Baxter (1974:4), nous dit que c'est dans la littérature de la fin des années 50, (articles sur l'Alaska), qu'apparaissent les premières indications documentées sur l'otite moyenne comme un problème majeur de santé (Kaplan *et al.* 1973; Baxter 1974).

Au Canada, Cambon en 1965, avait rapporté la présence de maladies de l'oreille moyenne chez les Indiens du Mont Currie en Colombie-Britannique et Palmer en 1968, avait présenté un rapport sur les difficultés d'audition chez les Indiens de l'Alberta (Baxter 1974:5). En 1969, Ling, Coy et Levision amorcent une série de rapports sur les maladies de l'oreille et les troubles auditifs des populations inuit de la Terre de Baffin. Baxter produira de nombreux rapports sur la population enfantine du même territoire (1972-1974-1976-1977-1978-1984-1986). Les autres régions des Territoires du Nord-Ouest sont atteintes du même mal (Schaefer 1971; Brodovsky *et al.* 1976) et il en est de même pour la population du Labrador (Timmerman et Gerson 1978, 1980).

Au Groenland, Røjskjaer rapporte en 1972 que l'infection suppurative de l'oreille moyenne est une maladie très répandue (Baxter 1974:5). Il attribue cet état de fait au climat arctique, aux conditions sanitaires et à l'absence de traitement par des spécialistes.

L'otite moyenne: sa spécificité dans les populations inuit

Si une large documentation a été amassée sur les aspects cliniques de l'otite moyenne aiguë (McShane 1982; Bluestone 1986) et son épidémiologie, tel n'est cependant pas le cas pour l'otite moyenne chronique qui souffre d'un manque d'études bien structurées (Bluestone 1985:607). Il est d'ailleurs étonnant de constater combien la littérature ne distingue pas nécessairement l'otite moyenne aiguë de l'otite moyenne chronique et ce, même dans les études réalisées chez les populations autochtones où l'otite moyenne chronique est considérée 15 fois plus fréquente que chez les Caucasiens (Wiet 1980:14). Pour Baxter, le terme d'otite moyenne chronique implique qu'il s'agit d'une maladie qui ne peut se guérir et il suggère de le remplacer par «otite moyenne persistante» (dans Labbé et Moffat 1983:5).

Plusieurs raisons font croire que l'otite moyenne n'a pas toujours été prévalente dans la population inuit et Manning (1975:151) invoque les suivantes:

1. La majorité des adultes de la population inuit ont un tympan d'apparence normale sans évidence d'aucun processus de guérison et qui donne la forte impression qu'ils n'ont pas souffert d'otite moyenne chronique quand ils étaient enfants.

2. Les adultes les plus âgés rapportent que leurs enfants n'ont pas eu d'écoulement d'oreille dans leur enfance.

3. Jusqu'à il y a environ 30 ans, les médecins ayant une expérience dans l'Arctique, n'ont pas rencontré une forte prévalence d'otite moyenne chronique.

4. Il y a quelques tympans où peut être observée une cicatrice. Ceci diffère complètement de la condition tympanique chez les adolescents et les jeunes adultes ayant une histoire documentée de 8 à 10 ans de maladie de l'oreille, qui ne donne aucun signe de guérison et qui n'ont aucune chance de retrouver la membrane tympanique intacte que montrent leurs parents.

La susceptibilité à la maladie n'est pas universelle chez les enfants inuit comme le montrent les résultats des recherches effectuées (Kaplan 1973; Baxter 1975; Manning 1975 et Spady 1985) car la fréquence varie selon les villages et les familles. Pour le Nouveau-Québec, les données épidémiologiques commencent à apparaître. La seule recherche dont nous disposons sur l'incidence de l'otite moyenne aiguë se limite à deux villages de la Baie d'Hudson (Dufour 1984b). Des données sur la prévalence de l'otite moyenne chronique et les troubles auditifs ont fait l'objet de deux publications (Baxter *et al.* 1986; Julien *et al.* à paraître) et se limitent à un village de la Baie d'Hudson. Les données sur les treize autres villages du Nouveau-Québec restent à venir.

Les recherches sur l'étiologie de l'otite moyenne

Distinguons d'abord l'otite moyenne aiguë de l'otite moyenne récurrente ou chronique qui se rencontrent chez les populations caucasiennes et chez les populations autochtones. Il existe cependant une différence et c'est une différence de degré: les autochtones (Inuit, Indiens, Aborigènes australiens et Maoris) montrent une incidence et une prévalence plus élevées (Hudson 1984; Wiet *et al.* 1980; Manning 1975; Bluestone *et al.* 1985). Par ailleurs, la maladie n'est pas commune en Afrique même chez les enfants connaissant des déficiences alimentaires et des infections comme la pneumonie et la tuberculose (Shaw 1981:349).

Toutes ces recheches sont cependant défectueuses selon Wiet *et al.* (1980:14) sur plusieurs points:

1. il y a variation entre les études sur la complétude des dossiers révisés;

2. il y a également variation dans la définition de la maladie;

3. on y observe un manque de différenciation entre la maladie chronique ou récurrente et l'otite avec effusion persistante de l'oreille moyenne;

4. il y manque des données bactériologiques.

Les facteurs qui sont considérés comme prédisposants ou associés à l'apparition de l'otite moyenne ne sont pas exclusifs les uns des autres mais doivent être pensés en association. Je passerai en revue la génétique, l'immunité, l'anatomie, le mode alimentaire et l'alimentation, l'habitation, la sanitation et l'hygiène.

L'attribution d'une part de la responsabilité à la génétique des peuples (Manning 1975; Griffith 1979; Wiet 1980) à leur systèmes immunitaires (Palva 1976) ou à quelque chose de non clairement identifiée mais reliée à la différence ethnique (entendue dans le sens de race) (Biles 1980; Shaw *et al.* 1981; Wiet 1979, 1980) et l'explication de l'otite moyenne par une dysfonction anatomique ou un trouble de la physiologie (comme la longueur de la trompe d'Eustache, son horizontalité ou son inclinaison etc) (Griffith 1979; Miller 1979; Wiet 1980; Middaugh 1980) occupent une bonne place dans la littérature.

Le deuxième grand responsable à avoir suscité l'intérêt est le mode alimentaire et la composition de l'alimentation des nouveaux-nés et des nourrissons: allaitement maternel, biberon, alimentation mixte, sucre, etc. (Schaefer 1971, 1980, 1982; Timmerman *et al.* 1978; Manning 1975; Brodowsky *et al.* 1976; Baxter 1977, 1978; Forman *et al.* 1984; Ellestad-Sayed 1979; Spady 1983) pour ne nommer que les plus cités.

L'habitation en termes de grandeur disponible selon le nombre d'habitants, son taux d'humidité ou de sécheresse ou des autres conditions qui y sont rattachées suscitent beaucoup d'interrogations (Biles *et al.* 1980; Baxter 1974, 1977; Ellestad-Sayed 1979; Manning 1975; Miller 1979). La sanitation de la communauté et l'hygiène personnelle n'ont pas été négligés (Manning 1975; Bjerregaad 1983; Hudson *et al.* 1984) de même que le niveau socio-économique (Hudson *et al.* 1984; Manning 1975).

Du côté des sciences sociales, j'ai identifié trois textes ayant pour objet ce problème de santé; Miller 1979; Marshall et Marshall 1980 et Dufour 1984b. Miller est une géographe qui propose la technique de la cartographie pour illustrer la distribution de l'incidence. Sa démarche prend appui sur les données épidémiologiques fournies par la littérature, elle-même n'ayant pas effectué de collecte de données. Les deux autres recherches sont de type épidémiologique et mettent en relation l'otite et le mode alimentaire des enfants. Pour Marshall et Marshall, les enfants nourris au sein sont moins susceptibles d'être malades alors que je démontre que la fréquence de l'otite moyenne est élevée quel que soit le mode alimentaire.

Tour ces auteurs ont démontré passablement d'imagination dans leurs tentatives à vouloir élucider l'énigme de l'otite moyenne mais malheureusement, aucune étude n'est concluante. Toutes ces recherches réfèrent à un même et unique modèle: le modèle linéaire de la causalité qualifié également de modèle cartésien. Ce modèle écologique requiert quatre types d'information pour comprendre un problème de santé: des données cliniques, épidémiologiques, environnementales et comportementales. Si les trois premiers types sont documentés, tout le champ des pratiques socio-culturelles et du savoir empirique est absent.

Je propose que si le biologique ne peut tout expliquer, le culturel ne le peut pas non plus mais que les deux ensembles joints à l'épidémiologie peuvent éclairer une situation pour le moins restée obscure jusqu'à maintenant et qui tient au paradoxe suivant. La médecine clinique, tout en reconnaissant que les causes de la maladie sont liées à l'environnement le néglige car sa pratique s'adresse au physiologique et à l'individu non sur le milieu. Le thérapeute se limite à *agir sur le symptôme (Burgener 1982). Pour sa part,* l'épidémiologie, selon Philippe (1985), ne peut pas dans sa recherche procéder par induction biologique pour élaborer ses hypothèses parce qu'elle n'a pas accès ni au patient ni à son environnement: elle se rabat donc sur l'induction statistique. Goldberg (1982) rappelle de plus, que le modèle épidémiologique traite tous les facteurs de risque sur un même plan et ignore leurs interrelations. Dans ces conditions, il faut conclure que ni la médecine, ni l'épidémiologie, seules, ne peuvent répondre aux questions laissées en suspens.

L'objet de ma recherche sera justement, tout en me situant physiquement dans les conditions de la production de l'otite moyenne aiguë, d'analyser sa récurrence à partir des catégories autochtones de la maladie et des variables sociales et culturelles qui l'expliquent. Le but est d'en dégager le modèle cognitif dans le sens où l'entend Roy Rappaport (1967:237) qui réfère à la manière unique qu'a un peuple de se relier à son environnement et à l'Univers et qui détermine comment se prennent l'ensemble des décisions touchant tous les niveaux de la vie et de l'existence.

La santé des Inuit dans un contexte de diversité culturelle

Depuis le 16e siècle où le Nouveau-Québec reçut la visite des bateaux européens qui cherchaient le passage nord-ouest vers l'Orient, la population inuit a transformé, modifié et rejeté certaines de ces caractéristiques sociales et culturelles dans le but de s'adapter aux nouveaux contextes. Le passage d'une société nomade à une société sédentaire est le résultat irréversible d'un ensemble d'événements et de circonstances que quelques auteurs ont documenté (dont Lachance 1979; Dorais 1984; Saladin d'Anglure 1984 et Duhaime 1985). Tous ces auteurs considèrent que c'est d'abord la traite des fourrures qui a modifié le rapport des autochtones à leur environnement par l'introduction, au début du siècle, d'une nouvelle technologie de chasse comme les fusils, les pièges, etc., qui, tout en facilitant les conditions de la chasse provoque des phénomènes écologiques tels que la diminution et la migration des espèces animales. Ensuite, c'est la conjoncture des années trente, la guerre puis la décroissance du marché des fourrures qui contribuera à l'appauvrissement des populations rendues plus vulnérables encore par les famines et les épidémies. C'est dans ce contexte que l'État, fédéral d'abord, dut intervenir vers la fin des années cinquante puis provincial ensuite, dans les années soixante. Si donc, dans un premier temps, la sédentarisation n'a été ni souhaitée ni voulue par personne (Simard dans Duhaime 1985:2), elle s'est avérée un mal nécessaire lorsque l'idée d'autosuffisance par la culture traditionnelle dut être abandonnée (Duhaime 1985). Cette période se caractérise par une prise en charge totale de l'État qui aura pour effet d'enlever à la population la capacité de se prendre elle-même en charge: l'État se substituant à elle (Duhaime 1985).

Plus strictement dans le domaine de la santé, parce que toute culture tend à croire que ses valeurs et ses façons de faire sont justes et universelles (Paul 1953:42), le nouveau système de médecine s'est implanté et imposé au Nord sans qu'il soit tenu compte non seulement de ce que les Inuit en pensaient mais aussi et surtout sans effort ni d'adaptation, ni de compréhension de leur culture. Ceux-ci, de leur côté, parce que le principe de Benjamin Paul s'applique aussi à eux, n'ont pas osé intervenir d'eux-mêmes. Du point de vue de la population pourtant, il faut parler d'un nouveau système pour penser la santé et la maladie puisqu'un autre système l'avait précédé: un vaste système complexe de croyances et de pratiques qui ne dissocie pas le corps et l'esprit en deux entités différentes, non plus qu'il ne coupe l'humain de l'environnement (Saladin d'Anglure 1984:495).

On assiste donc dans la société actuelle à une présence simultanée d'au moins deux modèles cognitifs pour un même problème de santé: les professionnels de la santé partagent entre eux *un* modèle bio-médical alors que la population elle, recourt probablement à un autre, si ce n'est pas *des* autres modèles d'explication et d'interprétation de la maladie.

Afin de permettre à mon modèle théorique d'intégrer la dimension historique donc de tenir compte du contexte de communication intraculturelle (famille-enfant, mère-enfant) et interculturelle (inuit-personnel médical) j'ai retenu trois axes-clé qui se justifient par leur importance par rapport aux questions posées: l'axe intégration-désintégration, l'axe compétence-dépendance et l'axe fermeture-ouverture que j'emprunte à Bibeau-Corin *et al.* (1985:16-18).

L'axe intégration-désintégration réfère au phénomène récent de la sédentarisation qui a regroupé dans une grande communauté l'ensemble de la population inuit en 14 villages alors que traditionnellement «les Inuit n'ont jamais développé de structures politiques collectives dépassant les cadres de la bande familiale» (Lachance 1979:302). Localement, dans chaque village, l'histoire du peuplement des villages montre que si certaines familles entretiennent des liens depuis plusieurs générations et constituent donc une communauté intégrée en termes de réseaux naturels d'entraide, de support, d'échanges etc., d'autres familles considérées comme étrangères sont mises dans la quasi impossibilité de s'intégrer. L'axe compétence-dépendance réfère au contrôle qu'ont les membres de la communauté de ce qui se passe dans leur communauté, à leur compétence et leur autonomie concernant le maintien de leur santé ou son recouvrement. L'axe ouverture-fermeture s'impose à cause de sa pertinence comme facteur de facilitation ou de contrainte par rapport à l'implantation des services dans une communauté, par rapport aux relations de la population avec les intervenants.

Le cadre théorique

La recherche s'inscrit dans le cadre théorique de l'anthropologie sociale et culturelle et s'inspire des travaux de l'anthropologie médicale dont les cinq concepts sont repris un peu plus loin, des théories sur le système (Bertalanffy 1973; Rosnay 1975; Capra 1983; et Tremblay 1983), des travaux de Bateson, Birdwhistell, Goffman, Hall, Jackson, Scheflen, Sigman et Watzlawick (1972-1981) sur la communication. Mais définissons d'abord l'otite moyenne. Du point de vue clinique, la distinction entre l'otite moyenne aiguë et l'otite moyenne chronique dépend soit du nombre d'otites, soit de leur durée. Du point de vue opérationnel, si l'otite moyenne aiguë se reproduit au point de maintenir ouverte la perforation tympanique, c'est que les conditions la produisant se trouvent aussi souvent réunies, aussi fréquemment que son incidence. C'est donc qu'il y a la présence d'un système, d'un système qui fonctionne bien. L'objectif de la recherche est de mettre à jour ce système. Selon Phillips (1985:31), l'anthropologie médicale s'alimente des cinq concepts théoriques suivants:

a) le modèle ethnomédical de Fabrega (1975)

b) le modèle biopsychosocial d'Engel (1977)

c) la dichotomie disease/illness d'Eisenberg (1977)

d) le réseau sémantique de la maladie de Good (1977 et 1981)

e) le modèle explicatif et l'approche par négociation de Kleinman (1980)

Les deux premiers modèles se veulent une approche alternative à celle centrée sur la biologie. De Fabrega, je retiens l'intérêt pour le fonctionnement socio-culturel de l'individu et de ses attentes en précisant cependant sa limite quant à la réduction qu'il fait du problème bio-médical qui se trouve minimisé. Quant à Engel, avec lequel on ne peut qu'être d'accord, son concept est trop général pour s'appliquer. La contribution de l'étude de la dichotomie disease/illness est importante et essentielle à la présente recherche et se situe au centre de la relation intra-culturelle et interculturelle. L'otite moyenne est la «disease» diagnostiquée et traitée par les professionnels de la santé alors que «l'illness» est l'expérience vécue par l'individu. Dans le cas d'un enfant, c'est la reconnaissance d'abord de «l'illness» par la mère, donc la communication intraculturelle qui est mise en cause, pour conduire à la décision de la consultation au dispensaire. C'est la consultation au dispensaire qui transformera «l'illness» en «disease» et mettra en cause la communication interculturelle: la mère, ou son substitut, avec le personnel médical.

De Good, à qui revient l'idée d'attribuer la détérioration du «care» ou modèle empirique du raisonnement clinique et qui propose un nouveau langage de médecine (le réseau sémantique de la maladie), je retiens les valeurs pratiques des concepts anthropologiques comme le symbole, la signification et l'interprétation.

Finalement pour Kleinman, ce n'est pas *un* modèle que le patient a en tête lors d'un épisode de maladie mais *trois*: un modèle populaire, un modèle familial et un modèle individuel alors que le clinicien en utilise deux différents: le modèle théorique et le modèle clinique. L'épisode de la maladie est le moment d'interaction de tous ces modèles et sa compréhension donne au clinicien l'opportunité d'intervenir et de changer le système dans la direction désirée. Pour cela, Kleinman a développé le modèle de négociation de la pratique clinique (negotiation model of clinical practice), dans lequel le clinicien découvre le modèle explicatif du patient pour l'actuel épisode de maladie, présente son propre modèle explicatif, compare les différents modèles explicatifs obtenus, liste les différents problèmes de la maladie (illness) et négocie un plan de traitement comme le fait un expert consultant avec

un client qui conserve l'autonomie et la responsabilité première de l'action (Kleinman 1978:430, cité par Phillips 1985:32). C'est là cependant un modèle de la pratique clinique psychiatrique inapplicable dans le cas présent.

Puisque j'ai écarté le modèle cartésien de la causalité, il me faut maintenant référer à la rétroaction et à la circularité qui constituent le modèle de causalité dans une théorie des systèmes en interaction selon Bateson et Watzlawick (1972). Le système est un ensemble d'objets et les relations entre ces objets et entre leurs attributs. Dans ce système, les objets sont les composantes ou éléments du système, les attributs sont les propriétés des objets et les relations, ce qui fait tenir ensemble le système; le milieu lui est l'ensemble de tous les objets de telle façon qu'une modification dans leurs attributs affecte le système ainsi que les objets dont les attributs sont modifiés par le comportement du système (Hall et Fagen, cité par Watzlawick 1972: 120–1). Il devient impossible de distinguer le système du milieu ou le sous-système du système mais c'est là aussi le caractère «insaisissable et souple» du concept qui n'est pas étranger à l'efficacité de la théorie comme le démontre les systèmes organiques. En résumé, je pourrais avancer que ce qui a fait difficulté jusqu'à maintenant dans la recherche sur la production de l'otite moyenne c'est que tout en sachant que le système organique est un système ouvert, c'est-à-dire qui échange avec son milieu de la matière, de l'énergie et de l'information, en pratique on a presque réduit le modèle à un système fermé.

Les trois propriétés de ce système ouvert qui s'appliquent à l'interaction sont: la totalité, la rétroaction et l'équifinalité. *La totalité* signifie que le système constitue un tout cohérent et indivisible: la modification d'un de ses éléments entraînera une modification des autres éléments et du système tout entier. La totalité s'oppose à la sommativité et à l'unilatéralité des réactions relationnelles. *La rétroaction* signifie que si les éléments d'un système ne sont pas reliés de façon sommative et unilatérale c'est la rétroaction et la circularité qui en constitue le modèle de causalité (Watzlawick p. 126). *L'équifinalité* signifie que les mêmes conséquences peuvent avoir des origines différentes parce que c'est la structure qui est déterminante. Elle signifie aussi que son corollaire est également exact: que des effets différents peuvent avoir les mêmes «causes» puisque les paramètres du système peuvent l'emporter sur les conditions initiales.

En d'autres termes, la configuration des facteurs qui produisent l'otite peut être différente d'un enfant à un autre. En accord avec l'équifinalité, je stipule que:

1. des conditions initiales différentes peuvent produire l'otite
2. des conditions initiales identiques peuvent produire l'otite et d'autres maladies
3. la configuration des «facteurs» peut différer d'un enfant à un autre.

La nature des hypothèses dans cette perspective théorique

Puisque l'otite moyenne est ici vue comme «l'output» d'un système, la formulation des hypothèses s'en trouve modifiée. Celles-ci doivent être formulées en termes de points de repère, c'est-à-dire, des lieux de blocage, de bifurcation et même de boites noires du système à partir des trois grands axes retenus.

Les hypothèses reliées à l'axe intégration — désintégration

1. La société inuit offre des conditions initiales de production de l'otite moyenne aiguë qui sont similaires ou semblables à celles des autres sociétés occidentales;

2. La société inuit offre des conditions de reproduction de l'otite moyenne qui sont différentes des autres sociétés occidentales;

3. Les familles non-intégrées et marginalisées du village sont exclues des réseaux naturels de circulation de la nourriture et des biens, des réseaux de camps, des réseaux d'entraide comme peuvent l'être les orphelins, les étrangers, les membres d'un autre clan, etc., et sont particulièrement intéressantes en regard de la production ou de la non-production de l'otite moyenne.

4. La possibilité existe d'une inadaptation au mode de vie moderne c'est-à-dire qu'il y aurait maintien d'un comportement traditionnel dans un nouveau contexte de vie.

Hypothèse reliée à l'axe compétence — dépendance

5. L'hypothèse réfère à la compréhension autochtone de l'otite moyenne qui est liée non seulement aux connaissances anatomiques et physiologiques, aux critères d'identification des symptômes, de la classification de la maladie, des formes différentes que peut prendre son diagnostic et son traitement. Je la définis de la manière suivante: la compréhension autochtone de la maladie en général et de l'otite en particulier entre en contradiction avec la compréhension bio-médicale des professionnels de la santé ce qui entraîne un retard ou une absence de consultation au dispensaire, la non «compliance», etc.

Hypothèse reliée à l'axe ouverture — fermeture

6. Je pose comme sixième hypothèse que l'interculturalisme auquel oblige le contexte nordique pose moins la question de l'accessibilité physique au système de soins que le problème de l'accessibilité culturelle en termes de problèmes multiples de communication et que des «blocages de circuit» existent des deux côtés et jouent un rôle dans la production de l'otite moyenne.

La méthodologie et l'analyse

La méthodologie comprend d'une part un relevé de la littérature et d'autre part, une collecte de données. J'ai choisi d'utiliser deux méthodologies afin d'analyser successivement mes données selon deux schémas analytiques. Chacune des méthodes me fournira un point de vue, une carte et le couplage des deux systèmes devra montrer les points du système conduisant à la production de l'otite moyenne. J'appelle les deux méthodes l'une, la construction de l'épidémiologie sociale et culturelle: construction comparative de l'otite et la seconde, la construction culturelle: métaphore sur l'otite.

La construction de l'épidémiologie sociale et culturelle: construction comparative de l'otite

Cette méthode réfère à celle de l'épidémiologie sociale mais s'en distingue toutefois. Son unité de base est la comparaison: comparaison des enfants avec otites — enfants sans otite; familles avec otite — familles sans otite. La collecte des données sera faite à l'aide d'entrevues ouvertes et semi-dirigées et l'analyse comparera les populations cibles pour faire surgir les petites différences qui finissent par faire toute la différence. Ma méthode différera cependant de l'épidémiologie sociale car je ne retiens de cette méthode que la délimitation des populations et les catégories de variables pour négliger la collecte et l'analyse statistiques. La deuxième activité visera à établir l'histoire sociale de l'otite. Ce sont les personnes âgées qui sont les plus susceptibles de détenir cette information. Il me faudra également voir dans la littérature les mentions qui pourraient être faites sur les variables suivantes: l'otite existait-elle dans la société plus ancienne? Quels étaient les problèmes de santé à cette époque? Quand est apparue l'otite? Est-ce un problème nouveau? D'autres problèmes sont-ils apparus en même temps? Quel était l'état de santé des enfants à cette époque? Aujourd'hui? Les enfants qui aujourd'hui font des otites auraient-ils survécu dans la société ancienne? Aurait-on pû la traiter? Comment?

La troisième activité visera à établir *l'histoire naturelle* de l'otite et son *histoire familiale*. Pour l'histoire naturelle de l'otite, les personnes les plus susceptibles de fournir l'information sont d'abord les mères et les grand-parents mais également les personnes extérieures au problème et qui ont leur opinion sur les familles dont les enfants sont malades et sur celles dont les enfants ne le sont pas. Les éléments que je retiens pour constituer le schéma d'entrevue sont: a) le lexique sur l'anatomo-pathologie de l'oreille: les sortes d'otites, les autres pathologies de l'oreille, la surdité, les problèmes d'audition; b) les caractéristiques des enfants touchés; c) l'âge et la saison la plus propice; d) les symptômes; e) qui pose ou ne pose pas le diagnostic; f) le traitement populaire (qui peut être le non-traitement) et médical ou autre, sa durée, son efficacité, etc.

L'histoire familiale de l'otite comprendra au moins les éléments suivants: a) qui fait ou a fait des otites dans la famille nucléaire et étendue afin de constituer des génogrammes; b) le statut des enfants selon qu'ils font ou non des otites: sexe, adoption, orphelin, l'éponymie; c) la circulation des enfants dans la journée, dans la semaine; d) qui prend soin de l'enfant; e) qui le traite lorsqu'il est malade, etc.

La construction culturelle: métaphores sur l'otite

Dans cette approche méthodologique, l'otite est moins considérée comme une maladie que comme un symptôme: l'output du système. Il y a l'otite comme symptôme mais il y a aussi beaucoup d'autres symptômes de dérivation. Mon outil doit donc en quelque sorte me permettre de ne retenir qu'une catégorie de symptômes — cette recherche ne s'intéressant qu'à une seule maladie. Il ne faut donc pas aborder l'otite par l'otite mais par autre chose et ce sera par l'oreille et l'audition.

La collecte de données aura pour objet le discours métaphorique sur l'oreille et l'audition. Pour l'instant, j'identifie deux niveaux au discours métaphorique: l'imaginaire libéré dans la mythologie, la légende et le conte et le langage métaphorique pour parler de la réalité. Dans le premier cas, il faudra encore ici, faire l'inventaire de la littérature mythologique (y compris la production artistique) ayant trait en particulier, à l'audition, aux oreilles, au corps et peut-être à la communication (ex: corps sans oreille) et faire une collecte de données sur le terrain avec les mêmes éléments. Dans le deuxième cas, les seuls repaires identifiés sont: comment la famille vit-elle l'otite? Comment la dit-elle? Comment la mère (les parents) médiatise-t-elle la douleur, les pleurs? Comment se fait l'accès au monde lorsqu'il y a absence d'ouïe? Par les autres sens? Y a-t-il brouille dans la communication? Pourquoi les Inuit sont-ils affectés dans leur audition? Fermeture possible à quelque chose de dangereux? Et l'enfant qui n'a pas d'otite (l'antithèse), à quoi cela lui donne-t-il accès? De quoi est-il privé?

Il m'est impossible, à ce moment-ci, de préciser ma démarche parce que je ne possède pas de définition préalable de l'otite, le but de l'exercice étant de la construire. La méthode consiste à me doter de points de repères et de concepts pour reconnaître le corps «sourd». Ma méthode devra donc en être une d'aller-retour: construire à partir de la théorie, des données de l'observation et du discours populaire etc; confrontation de ce construit par sa discussion pour déterminer ce qui doit à nouveau être observé, redocumenté; à nouveau confronté pour finalement définir l'otite.

Références

Bateson, Birdwhistell, Goffman, Hall, Jackson, Scheflen, Sigman et Watzlawick. La nouvelle communication, Seuil 1981.

Baxter, J.D., Ling, D. 1972. Hearing Loss Among Baffin Zone Eskimos, A preliminary Report, Canadian Journal of Otolaryngology, 1:337-343.

Baxter, J.D. et Ling, D. 1974. Ear disease and hearing loss among the Eskimo population of the Baffin Zone, Canadian Journal of Otolaryngology, 3:110-122.

Baxter, J.D. 1976. Ear disease among the Eskimo population of the Baffin Zone. Circumpolar Health, Proceedings of the 3rd International Symposium on Circumpolar Health, Toronto Press, p. 385-389.

Baxter, J.D. 1977. Chronic otitis media and hearing loss in the Eskimo population of Canada. The Laryngoscope, Vol. LXXXVII (9) p. 1528-42.

Baxter, J.D. 1978. The evolving attitude in Canada toward the treatment of chronic otitis media in its Inuit (Eskimo) population. Abstracts of the 6th International Symposium on Circumpolar Health, Vol. 2, p. 243.

Baxter, J.D. 1984. The evolution of chronic otitis media in the Inuit of the Eastern Canadian Arctic and its managerial implication. Abstracts of the 6th International Symposium on Circumpolar Health, p. 36.

Baxter, J.D., Ilecki, H.J., Julien, G., et Tewfik, T.L. 1986. Observations on the prevalence of ear disease in the Inuit and Cree Indian school population of Kuujjuaraapik. Journal of Otolaryngology, Vol. 15, No. 1, p. 25-30.

Bertalanffy, Ludwig Von 1968. Théorie générale des systèmes, Dunod, Paris, 296 pages.

Bibeau, Gilles, Corin, Ellen, Martin, Jean-Claude et Sachel, Alain. 1985. Le contexte social et culturel des problèmes socio-sanitaires en Moyenne Côte-Nord. Rapport présenté à la Direction des Services Communautaires du Centre de Santé St-Jean-Eudes, au Havre St-Pierre, 200 pages.

Biles, R.W. Buffler, Patricia A., et O'Donnell, Alice A. 1980. Epidemiology of otitis media: A community study. American Journal of Public Health, Vol. 70, No. 6, p. 593-598.

Bjerregaard, Peter 1983. Housing standards, social group, and respiratory infections in children of Upernavik, Greenland. Scandinavian Journal of Social Medecine, II:107-111.

Bluestone Charles D. et al. 1983. Workshop of effects of otitis media on the child. Pediatrics, Vol. 71, No. 4.

Bluestone Charles D. et al. 1985. Consensus: management of the child with a chronic draining ear. Pediatric Infections Disease, Vol. 4, No. 6 p. 607-612.

Bluestone Charles D. et al. 1986. Controversies in screening for middle ear disease and hearing loss in children. Pediatrics, Vol. 77, No. 1, p. 57-70.

Bodor, F.F., Barenkamp, S.J., Marchant, C.D., et Shurin, P.A. 1985. Bacterial etiology of conjunctivitis — otitis media syndrome. Pediatrics, Vol. 76, No. 1, p. 26-28.

Brodovsky, D., Hildes, J.A., Medd, L.M. et Woolf, C. 1976. Chronic otitis media in the Keewatin district. Circumpolar Health, Proceedings of the 3rd International Symposium on Circumpolar Health, Toronto Press, p. 399-403.

Bungener, Martine 1982. L'épidémiologie prisonnière de la pratique médicale et de la fonction sociale de la médecine. Sciences sociales et santé, Décembre, p. 111-122.

Capra, Fritjof 1983. Le temps du changement. Rocher.

Dorais, Louis-Jacques, 1984. Les Tuvaalummiut. Histoire sociale des Inuit de Quaqtaq (Québec Arctique), Recherches Amérindiennes au Québec, Collection Signes des Amériques, 209 pages.

Dufour, Rose, 1984a. Allaitement maternel et adoption chez les Inuit du Québec Arctique. Canadian Journal of Public Health, 75:137-40.

Dufour, Rose, 1984b. L'otite chez les enfants inuit: une question de mode alimentaire? Etudes Inuit Studies, Vol. 8, No. 2, p. 77-89.

Duhaime, Gérard, 1985. De l'igloo au H.L.M. Les Inuit sédentares et l'Etat-providence. Centre d'études nordiques, Université Laval, 81 pages.

Eisenberg, Leon, 1977. Disease and illness — Distinctions between professional and popular ideas of sickness. Culture, Medicine and Psychiatry, 1:9-23.

Ellestad-Sayed, Judith et al. 1979. Breast-feeding against infection in Indian infants. Canadian Medical Association Journal, Vol. 120:295-300.

Engel, George L. 1977. The need for a new medical model: A challenge for bio-medicine. Science, 196:129-136.

Fabrega, Horatio Jr. 1975. The Need for an Ethnomedical Science. Science, 189:969-975.

Forman, M.R., et al. 1984. The Pima Infant Feeding Study: Breast-feeding and respiratory infections during the first year of life. International Journal of Epidemiology, Vol. 13, No. 4, p. 447-453.

Goldberg, Marcel, 1982. Cet obscur objet de l'épidémiologie. Sciences sociales et santé, Déc. 1982, p. 55-110.

Good, Byron J. 1977. The heart of the matter: the semantic of illness in Iran. Culture, Medicine and Psychiatry, 1:25-58.

Griffith, Thomas E. 1979. Epidemiology of otitis media: an interracial study. The Laryngoscope, 89:22—30.

Hudson, M.H. et Rockett, I.R.H. 1984. An environmental and demographic analysis of otitis media in rural Australian Aborigenes. International Journal of Epidemiology, Vol. 13, No. 1, p. 73-81.

Jeliu, Gloria et Forget, Guy 1983. Les otites moyennes chez l'enfant. Actualité médicale, 16 nov.

Julien, G. et al. A paraître dans Canadian Journal of Public Health. Chronic otitis media and hearing deficit among native children of Kuujjuaraapik. (Northern Quebec): A Pilot Project.

Kaplan, Gary J. et al. 1973. Long-term effects of otitis media. A ten-year cohort study of Alaskan Eskimo children. Pediatrics, Vol. 52, No. 4, 577-584.

Kleinman, Arthur 1978. Relevance of anthropological and cross-cultural research: concepts and strategies. American Journal of Psychiatry, 135:427-431.

Kleinman, Arthur 1980. Patients and Healers in the Context of Culture. Berkeley University of California Press.

Labbe, Jean et Moffat, Michael, 1983. Colloque sur l'otite et l'audition chez les enfants autochtones — Hôpital de Montréal pour enfants. (Compte-rendu).

Lachance, Denis, 1979. Les Inuit du Québec. Perspectives anthropologiques. Editions du Renouveau Pédagogique, p. 289-303.

Manning, P.J., 1975. The nutritional basis of otitis media. J.C. Hawthorne Ed. Nutrition of Indians and Eskimo Children. Report of the second Canadian Ross Conference on Pediatric Research — Ross Laboratories, Montréal.

Marshall, Leslie B. et Marshall, M. 1980. Infant feeding and infant illness in a Micronesian Village. Social Science & Medicine, Vol. 14B, p. 33-38.

McShane, Damian, 1982. Otitis Media and American Indians: Prevalence, Etiology, Psychoeducational Consequences, Prevention and Intervention. New directions in prevention among American Indian and Alaska native communities. Spero M. Manson Ed. National Centre for American Indian and Alaska Native Mental Health Research — Oregon Health Sciences University.

Meilleur, Ghislaine et Mishra, Thérèse, 1981. Bilan des otites moyennes. Séminaire d'épidémiologie du jeudi 23 avril — Département de santé Communautaire. Hôpital Maisonneuve — Rosemont.

Middaugh, J. 1980. Blue Ribbon Committee on Otitis Media and Hearing Impairment — Manuscript, 45 pages — Services de santé — Alaska.

Miller, Mary Lou, 1979. Epidemiology of otitis media: problem and research focus for geographers. Social Science and Medicine, Vol. 13D, Dec. p. 233-6.

Palva, A. 1976. The problem of chronic otitis media in northern Finland. Circumpolar Health, Proceedings of the 3rd International Symposium on Circumpolar Health — Toronto Press, p. 403-408.

Paradise, J.L. et Rogers, Kenneth D. 1980. Ubiquitous otitis media: A child health problem of uncertain dimension. American Journal of Public Health. Vol. 70, No. 6, 577-578.

Paradise, J.L. et Rogers, Kenneth D. 1986. An otitis media child development, and tympanostomy tubes: New answers or old questions? Pediatrics, Vol. 77, No. 1:88-92.

Paul, Benjamin D. 1953. Respect for Cultural Difference, Community Development Bulletin, Vol. 4, p. 42-47.

Philippe, Pierre, 1985. Génération et évaluation des hypothèses étiologiques en épidémiologie. Social Science & Medicine, Vol. 20, No. 7:681-689.

Phillips, Michael R. 1985. Can "Clinically Applied Anthropology" survive in medical care settings? Medical Anthropology Quarterly. Vol. 16, No. 2:31-36.

Rappaport, Roy . 1967. Pigs for the Ancestors — Ritual in the Ecology of a New Guinea People. Yale University Press.

Rosnay, Joël de, 1975. Le Macroscope — Vers une vision globale. Seuil.

Saladin d'Anglure, Bernard, 1984. Inuit of Quebec p. 476-502. Contemporary Inuit of Quebec p. 683-688. Handbook of North American Indians. Smithsonian Institution, Washington.

Schaefer, Otto, 1971. Otitis Media and Bottle-feeding. An epidemiological study of infant feeding habits and incidence of recurrent and chronic middle ear disease in Canadian Eskimos. Canadian Journal of Public Health. Vol. 62:478-488.

Schaefer, Otto et al. 1980. General and nutritional health in two Eskimo populations at different stages of acculturation. Canadian Journal of Public Health, Vol. 71:397-405.

Schaefer, Otto et Spady, D.W. 1982. Changing Trends in Infant Feeding Patterns in the Northwest Territories 1973-1979. Canadian Journal of Public Health, Vol. 73:304-309.

Shaw, James R. et al. 1981. Observations on the relation of environmental and behavioral factors to the occurrence of otitis media among Indian children. Public Health Reports, Vol. 96, No. 4, p. 342-349.

Spady, D.W. 1983. Between two worlds. Boreal Institute for Northern Studies. Occasional Publication, Vol. 16.

Timmermans, F.J.W. et Gerson, S.S. 1978. Bottle-feeding and chronic otitis media in Eskimo children in Labrador. Abstracts — 4th International Symposium on Circumpolar Health, Vol. 2, p. 250-251.

Timmermans, F.J.W. et Gerson S. 1980. chronic granulomatous otitis media in bottle-fed Inuit children. Canadian Medical Association Journal, Vol. 122, p. 545-547.

Tremblay, Marc-Adélard, 1983. Une perspective holistique dans l'étude de la santé. A holistic approach in the study of health. Mémoires de la société Royale du Canada, Série IV, Tome XXI, 1983.

Watzlawick, P., Beavin, J.H., et Jackson, D. 1972. Une logique de la communication. Seuil.

Wiet, Richard J. 1979. Patterns of Ear Disease in the Southwestern American Indian. Arch. Otolaryngology. Vol. 105, p. 381-385.

Wiet, Richard et al. 1980. Natural history of otitis media in the American Native. Annals of Otorhinolaryngology. Vol. 89, May-June, p. 14-19.

*En raison des contraintes d'espace, je n'ai retenu ici que les références citées. Une bibliographie plus exhaustive du sujet est disponible sur demande.

**Je remercie les membres de mon comité de thèse, M. Marc-Adélard Tremblay, Mad. Ellen Corin et M. Yvan Simonis, mes maîtres dans cette démarche de recherche. Je remercie également Jacques Grondin pour les bibliographies qu'il a élaborées sur l'otite moyenne et sur l'ethnomédecine inuit et Teresa Herrera-Sherif à qui je dois l'idée de la construction culturelle de l'otite par la métaphore.

AN INVESTIGATION OF WRITING ACROSS THE CURRICULUM IN AN EASTERN ARCTIC SCHOOL

Marta Fasiolo and Ronald Mackay

Centre for the Teaching of English as a Second Language, Concordia University, Montreal, Quebec H3G 1M8

Level: M. Fasiolo, Bachelor's

Abstract

This pilot study describes the various roles that writing appears to play in the education of Inuit secondary school students in the Eastern Arctic.

The researcher, as participant observer, attended an entire week each of classes with grade 7 and with grade 9 students in a Baffin Region school. All writing tasks demanded of the students were noted and a broad sample of the students' written responses to these demands were obtained.

From this, a detailed description of the types of writing tasks set, the guidance given to the student and the students' performance of the tasks was produced.

All teachers of these two grades were interviewed as were a broad sample of students from each of the two grades, to obtain their perceptions of the function and value of the writing tasks set.

The results of the interviews along with the descriptive data allowed the researchers to examine and try to explain discrepancies between the teachers' intentions underlying the use of writing tasks as part of the educational process and the students' actual experience of responding to these tasks.

A tentative explanation (small 't' theory) is offered to account for the problems contributing to the relatively poor performance of Inuit secondary school students receiving their education through the medium of English, their second language.

Suggestions are made for resolving or circumventing some of these problems.

Key words: Education, Inuit, high school, English, writing, Eastern Arctic.

Résumé

L'auteure décrit les divers rôles que la rédaction semble jouer dans l'éducation des élèves inuit d'une école secondaire de l'Arctique oriental.

L'auteure, participant en observatrice, a passé une semaine entière avec des élèves de 7^{e} année et une autre avec des élèves de 9^{e} année dans une école régionale de l'île de Baffin. Tous les devoirs écrits exigés des élèves ont été annotés et l'auteur a obtenu un large échantillonnage des réponses écrites des élèves. Grâce à leur analyse, l'auteure fait une description détaillée des genres de rédactions proposés, des directives données aux élèves et des résultats obtenus par ceux-ci.

L'auteure s'est entretenue avec tous les enseignants de ces deux classes ainsi qu'avec un large échantillonnage de leurs élèves, afin d'obtenir leur opinion sur les objectifs et la valeur des travaux de rédaction proposés.

Le résultat des entrevues et les données descriptives recueillies ont permis d'examiner et de chercher à expliquer les contradictions entre les intentions pédagogiques des enseignants qui utilisent ces rédactions et l'expérience réelle des élèves accomplissant leur tâche. L'auteure offre une explication possible (presque une théorie) pour les problèmes qui causent les résultats plutôt médiocres obtenus par les élèves inuit du secondaire recevant un enseignement par le canal d'une langue seconde, l'anglais.

L'étude propose des moyens de résoudre ou de contourner certaines de ces difficultés.

Mots-clés: Éducation, Inuit, école secondaire, anglais, rédaction, Arctique oriental.

Understanding the Process of Native Education

Summarizing the 1982 recommendations of the Special Committee on Education of the Legislative Assembly of the NWT, the Minister of Education, the Right Honourable Dennis Patterson, said that the challenge facing the NWT was 'to provide nothing less than the most versatile, high quality education system in Canada'. Many of the 1982 recommendations are now being implemented in the Northwest Territories. One of those concerned strengthening regional control of education. The creation of the Baffin Divisional Board of Education in the fall of 1985 is an example of that recommendation being put into operation.

Increasing opportunities for regional control of schools and re-writing school curricula, however, important as they are, are not sufficient in themselves to ensure educational improvement. The part played in educational changes by teachers and students in the classroom is also crucial. To date, a descriptive account of what happens in Arctic classrooms for the purpose of increasing our understanding of the educational process experienced by Inuit students has been conspicuous by its absence.

Casual observations on the results of classroom instruction are not uncommon. Michael Shouldice of the Inuit Cultural Institute in Eskimo Point recently observed that:

> In some communities many students drop out of school before completing grade 9. Besides failing to develop marketable skills, these young people unfortunately often have poor communication skills in Inuktitut as well as English. Many of them wind up uneducated and unemployed.
>
> (Shouldice, 1986, p. 59).

If many Inuit students do indeed possess inadequate communication skills in Inuktitut and English, the consequences can be severe indeed, not merely after they leave school but

also during the time they spend at school. One specialist in educational linguistics neatly summarizes the importance of language in school:

> Without question, language is the single most important avenue of access to education. It is the principal medium through which language is acquired, and at the same time, it is the main mechanism through which learning is displayed. Knowledge through language is the indispensible public evidence that education has taken place. In this sense, language constitutes both means and ends in education.
>
> (Oller, 1978)

The study reported here is premised upon the belief that an understanding of the educational process occurring in Inuit schools requires first a thorough *description* of what actually takes place in the classroom — the roles of both the students and the teachers, the kinds of language demands made by English medium education on the students, the tasks set by the teacher, and the students' attempts and efforts at responding to these tasks. An appreciation of the crucial importance of observing and describing actual classroom events and understanding them in terms of the participants' perceptions is shared by educator and social scientist Richard Heyman, who suggests that we should —

> "devote our attention to the study of performance as a way of uncovering the work that teachers and Native children do in the classroom, which is commonsensically understood and labelled as teaching and learning."
>
> (Heyman, 1984, p. 12)

The perspective for this study

Those educators seeking to better understand the educational process so that they can help to contribute to its improvement choose to study issues which they feel most qualified to address. Some examine the relationship between the social and cultural background of students and their success in school; others examine the role of the students' mother tongue in promoting educational success; still others relate scores obtained on standardized tests with other variables such as different types of materials, the time allotted to a given subject, or the ethnicity of the teacher.

As applied linguists, we are interested in the role played by the English language in education. Our intention in this study was to address the fact that the medium of most school instruction for Inuit students in secondary school is English and to attempt to discover and describe what kinds of and how much writing in English (their second language) students were required to engage in as part of the normal day-to-day teaching/learning process.

The purpose of the study

The study focused specifically upon describing the role that writing in English plays in the education of Inuit students for whom Inuktitut, and not English, is their mother tongue. The questions that we addressed were, firstly:

> How much and what kinds of classroom writing, in English, are required of Inuit students in the first and last years of junior high school?

and

> How do teachers and students perceive the role of writing as part of the teaching/learning process?

The classrooms studied and the methods used

We studied one grade 7 and one grade 9 class, each for one week, in a school in the Eastern Arctic. With the cooperation of both teachers and students, one of the researchers participated in every class every day for a teaching week for each of the two grades. (Five days in the case of grade 7 and four in the case of grade 9). As a "participant observer," the researcher was able to observe the classroom interaction of teachers and students and make note of all writing tasks the students were required to perform, the amount of preparation given for them and time assigned to them, and how the students carried out the tasks — e.g., quickly or slowly, enthusiastically or otherwise, and with lengthy written responses or short ones.

The researcher supplemented these observations by photocopying samples of students' written work and by conducting structured interviews with 20 students and holding conversations with students and with teachers. The teachers also responded to a written questionnaire.

In a very real sense, the researcher "immersed" herself in the situation under observation and became part of it, albeit for a relatively short time.

One advantage of this naturalistic approach to educational investigation is that the researcher is to a very large extent able to take part in the educational process as it naturally occurs in a school. She can talk to the students and the teachers and be part of the interaction between them — hence the name 'participant observation' for this method of research.

The characteristics of this type of research are that the researcher gets close to or even becomes part of the group and context being observed, records as far as possible what actually happens, seeks to become familiar with the opinions or perceptions of those involved, and reports these observations as description and quotation.

Results

Variety of writing tasks based on classroom observation.

Writing tasks assigned by the teacher and engaged in by the students were grouped into five broad categories:

Copying
Writing individual sentences
Writing on work sheets
Taking dictation
and More extensive pieces of writing

There was a variety of subtasks included in each of these categories. The category 'Copying' for example included:

Copying individual words from the blackboard
Copying notes from the blackboard
Copying a diagram or chart
Copying notes from an overhead projector or transparency

Taking dictation tasks included:

Spelling tests

Writing sentences included:

Answering questions in written sentences
Taking notes

More extensive pieces of writing included:

Student making own notes
Student writing a paragraph or more
Creative writing

Writing on worksheets included:

Labelling a map
Supplying words to complete blanks
Listing pros and cons on a given issue
Labelling a diagram
Listing items
Matching items
Checking true or false statements

Distribution and duration of writing tasks based on classroom observation

During the period observed, writing tasks were set in the more obvious "subject matter" classes such as English, Social Studies, Science, English as a Second Language, Mathematics, and Home Economics, but not in the classes in which physical performance was predominant, such as Art, Physical Education, Music, and Vocational Training. No writing tasks were set, during the period of observation, in the Inuktitut class for either grade 7 or grade 9.

The writing tasks set varied from class to class. (See tables 1 and 2). Tasks also varied in both frequency and the amount of time assigned for the student to perform them. For example, although copying fromthe board was common to most classes, more extensive pieces of writing were set in no classes other than the grade 7 Socials and ESL classes and the grade 9 English and ESL classes.

Grade 7

Out of a total of 26 writing tasks given to grade 7, copying accounted for 11 (about 42%) of them, worksheet activity for 7 (about 27%), the writing of sentences and dictation for 3 (about 12%) each, and longer pieces of writing for 2 (about 8%).

Out of five days of classes (approx. 26 hours), time assigned to writing took up just under eight hours. Of that, almost three hours (about 37% of the time dedicated to writing) were spent on copying tasks, 1.75 hours on worksheet activity, 1.2 hours on writing sentences, .6 on dictation, and 1.5 on longer pieces of writing.

TABLE 1
Number, type and total duration of tasks in Grade 7 classes where writing was assigned.

Subject	No. of classes observed	Total time observed in minutes	Total time devoted to writing tasks in minutes	Total no. of writing tasks assigned	Copying	Worksheets	Dictation	Sentences	More extensive pieces of writing
Science	4	180	65	7	3	4	0	0	0
Socials	5	320	185	6	2	1	0	2	1
English	4	160	60	4	1	1	2	0	0
Math	3	70	60	4	4	0	0	0	0
Home Ec	2	80	35	3	1	0	0	1	0
E.S.L.	2	120	70	2	0	0	1	0	1

Grade 9

During the course of the four days of classes observed, grade 9 students were assigned 23 writing tasks. Of these, 7 (about 30%) were copying tasks, 8 (about 35%) were worksheet activity tasks, 4 (about 17%) involved longer pieces of writing, 3 (about 13%) involved the writing of single sentences, and one (about 4%) was a dictation.

Out of the four days of classes (approx. 21 hours), time assigned to writing took up just under five hours.

Of that, almost two hours were spent on copying, one and a quarter hours each on more extensive writing and on worksheet tasks, twenty-five minutes on writing sentences, and five minutes taking dictation.

TABLE 2
Number, type and total duration of tasks in Grade 9 classes where writing was assigned.

Subject	No. of classes observed	Total time observed in minutes	Total time devoted to writing tasks in minutes	Total no. of writing tasks assigned	Copying	Worksheets	Dictation	Sentences	More extensive pieces of writing
Socials	4	200	95	7	2	3	0	1	0
English	3	200	65	5	0	2	0	0	3
Home Ec.	3	120	25	4	2	1	0	1	0
Math	4	200	65	3	3	0	0	0	0
Science	2	120	15	2	0	1	0	1	0
E.S.L.	2	80	30	2	0	0	1	0	1

Language, learning and writing: the students' views. Preference for talking, listening, reading, writing

Of the four language modes used in class (vis., talking, listening, reading, and writing), the majority of the students interviewed preferred talking. The reasons they gave were that talking was 'fun', it was "better than working" and it broke the monotony of silence.

The second most popular medium was writing. Reasons offered ranged from 'just liking writing' to claims that it was better for learning and study purposes.

An equal number of students chose listening (because it is 'easier', you 'understand better' and 'learn faster') and reading (because it is 'relaxing', it takes your mind off things, and there is less noise).

On the other hand, in response to being asked which mode they learned most from, more than half of the students put listening first because they could 'ask questions' or 'understand better'. The teacher was considered as the authoritative source of information.

Fewer students, only 3 out of 20, selected writing as the mode they learned from most. Those who did, felt that writing was more contributive to study, it intensified individual practice and improved understanding.

Writing was perceived by 19 of the 20 students as more like 'work' than listening, speaking, or reading because it was tiring, it required physical dexterity and control in forming the letters, and was "too much".

Despite the fact that almost all of the students perceived writing as involving more work than speaking, listening or reading, they felt that there were advantages to be gained from writing tasks. These advantages included learning to write better, learning how to write a good story, improving spelling, improving study habits, and simply 'learning more'.

TABLE 3
Showing responses of the 20 students interviewed to questions relating to Talking, Listening, Reading, and Writing in School.

	Talking	Listening	Reading	Writing
Of these 4 things that happen in school, which one do you like most?	7	4	4	5
Which of them do you think you learn most from?	2	11	4	3
Which of them is most like work?	0	0	1	19

Preference for different types of writing: Most preferred

Of the various categories of writing they are asked to perform (copying, taking dictation, making notes, worksheets, sentences, and more extensive pieces of writing), most students preferred copying. Copying was most popular because it demanded 'no thinking' and it was 'easy'.

Next preferred was writing sentences because this involved working 'by yourself', and you had to 'understand more than copying'.

Third in the order of preference was writing more extensive pieces because you could 'create your own stories', 'use (your) imagination', and have 'fun' and 'adventure'.

Fourth in order of preference was dictation because it was 'better than copying from the board'.

Fifth (chosen by one student each) were making notes (no reason given) and worksheets because they were 'fun'.

Preference for different types of writing: Least popular

Least popular of the categories of written task were more extensive pieces of writing because such a task was 'boring' or involved 'thinking hard' or because 'thinking what to write' was too much of a burden.

Second in the least popular category was using worksheets because worksheets could be 'difficult', 'boring', were used too frequently or because they did not contribute to learning.

Third least popular was copying because it 'takes time', may involve 'drawing' and too little time may be allowed to complete it.

Dictation, making notes, and writing sentences were chosen as the least popular writing activity by one student each; none of the three could explain why the category they had identified was least liked by them.

Asked which of the categories of writing they learned most from, most chose copying. Writing sentences came second, longer pieces of writing third. Only one student felt he/she learned most from dictation and one from completing worksheets.

Which types of writing do you get most of?

When asked about the frequency with which they were asked to undertake the various categories of writing tasks, the vast majority, (16 students out of 20) felt that copying was the most frequently demanded.

TABLE 4
Showing views students hold about different types of writing tasks.

	Copying	Dictation	Making Notes	Worksheets	Sentences	More Extensive
Of the following kinds of writing which do you like most?	6	3	1	1	5	4
Which of them do you like least?	4	1	1	5	1	8
Which of them do you think you learn most from?	18	1	0	1	0	2
Which of them do you get most of in School?	16	0	0	1	1	2

Students' perceptions of the purpose of and preparation for writing tasks

The great majority of the students, 17 out of 20, perceived writing tasks as somehow intended to contribute to their learning. Several referred to the reference value of written work, others associated closely the activities of writing and testing. One student felt that, in setting writing tasks, teachers were 'just doing their job'.

As an effective means of preparing for writing tasks, most students (16) preferred a preliminary example worked out in class. Only three students chose an oral explanation by the teacher as being most helpful.

Who reads what is written in school?

Students were virtually unanimous in agreeing that teachers read what they, the students, wrote in school. In addition to having their assignments read by the teacher, 10 students answered that 'friends' read their assignments, 4 answered 'classmates', 6 answered 'brothers or sisters' and 3 said that their parents read their assignments.

Most students (14 out of 20) felt that it mattered to them that their teacher took the time to read what they had written and most felt it easier to write if they had an imaginary reader in mind.

So far as comments by the teacher on their written assignments were concerned, most students (13) were of the opinion that they learned more if these comments were oral. Only 3 found written comments more useful.

Who students think teaches them to write in school

Most students (12) perceived the English teacher as teaching them to write; the Social Studies teacher came a close second. A few thought that the English Second Language Teacher taught them writing and one thought that 'nobody' taught them to write.

Most students, (14 out of 20) believed that writing well could only be achieved by practice.

Students' perceptions of quantity of writing required by school

The largest proportion of students (10 out of 20) felt that there was "too much" writing required in school; 6 thought there was "just enough"; 4 thought that there was "too little".

Writing outside school

All students stated that they engaged in some form of writing outside of school. Writing letters was most frequently mentioned (16 out of 20). Other activities included homework, writing a diary or journal, writing at work, and writing associated with music or stories.

Teachers' perceptions of the types and characteristics of good writing in their subject areas

According to the teachers of science, that subject requires laboratory reports made up of descriptive sentences and paragraphs, short answers to questions, and written projects. 'Good writing' in science would be illustrated by "correct science concepts, good organization and style and correct grammar and spelling".

Mathematics requires 'simple statements in answer to written mathematical problems', specialized definitions and vocabulary, and the writing of numbers. Good writing in mathematics would display neatness, precision, and clarity as well as logical development.

Home Economics requires 'copying teacher-made notes from the board' and a 'small amount of writing to answer questions and very short assignments'.

Social Studies requires the student to make his/her own notes, to complete forms, to complete sentences, and to construct paragraphs. Good writing in Social Studies would be characterized by 'neatness, clarity, complete sentences, good grammar' and the presence of a 'main idea' in each paragraph.

English requires the writing of journals, expressive, descriptive and narrative prose, notes, and letters. Good writing in English would be exemplified by neatness, clarity, complete sentences, good grammar, the presence of a main idea in each paragraph, and a character of completeness in each assignment.

English as a Second Language requires mainly narrative and explanatory writing characterized by appropriateness of style, accurate spelling and grammar, and good organization, which involves the presence of main ideas, supporting ideas, and conclusions.

Teachers' perception of writing ability and their role in promoting it

Most teachers were of the opinion that there is a very close relationship between students' general writing proficiency and their ability to write well in their particular subject area. General writing ability was suggested by one teacher as helping with "organization and clarity in other areas". One teacher, however, the English teacher, pointed out that a *willingness* to write on the part of the students' was important in the development of proficiency. Willingness to write would promote practice, and practice would promote proficient writing in any given area.

The English and ESL teachers accepted responsibility for teaching students general writing ability. The English teacher considered it "very much my job to encourage students to see the value of writing in many contexts". The ESL teacher, while pointing out that the major burden of teaching writing has traditionally fallen to the English teacher and the ESL teacher, commented favourably on the fact that "other subject teachers are sharing this responsibility as time goes on."

Teachers of other subjects varied in their perception of their pedagogic responsibilities as including the teaching of writing. The teachers of Mathematics and Home Economics were of the opinion that writing ability was of only marginal relevance to successful performance in these subjects. They stressed that the focus of their teaching was on the content of the subject matter. The Home Economics teacher was of the opinion that copying notes accurately off the board was the writing skill most relevant to that subject.

The Mathematics teacher echoed the opinion of the Science teacher, both of whom felt that they taught their students "the amount of writing necessary" for passing their particular course. They were willing to teach the student to write grammatically correct answers to the tasks assigned within the boundaries of their subjects — laboratory reports in the case of Science and 'precision and clarity' and 'good organization and note-taking' in the case of Mathematics.

The Social Studies teacher, while not perceiving the teaching of general writing ability as "my first responsibility' added that nonetheless, if writing skills (of students) are very weak, 'English' teaching may be necessary as a preparation for doing some Social Studies assignments. Social Studies assignments might require the writing of 'sentences and paragraphs', the taking of 'notes', organizing a project or paper, and stating arguments for or against a particular issue.

Teacher perception of the importance of writing outside of school

Teachers' perceptions of the importance of writing outside the school context suggest that students 'write very little outside of school' except for the occasional completion of an application form. One teacher reports that 'very few write letters to relatives or friends' and another that there appears to be little or no 'immediately perceivable value to writing apart from school'. That teacher sees the role of writing in school not as a preparation for immediate application in the world outside, but 'as enjoyment, as a thinking process and as a form of self-understanding' which can contribute to the students' participation in their own learning. Another teacher points out that writing is the means by which students demonstrate their mastery of what has been learned at school, not, in the first instance, as a tool for use in their private lives.

Some teachers do point out the career value that writing may have to a student in the future if he or she were to enter government service, broadcasting, or journalism or continue education to a more advanced level.

How teachers teach writing

Most teachers used examples to demonstrate to students the kinds of writing expected of them in their specific subject areas.

Typical techniques described were 'doing examples on the board for the first few (tasks). The students copy. Then they are required to do them (by themselves)'. The presentation of such 'model responses' was a characteristic strategy used by the Social Studies, Science, and Math teachers concerned primarily with writing tasks which contribute directly to the mastery of their subjects.

The English and ESL teachers, as strategies for improving students' writing, referred to teaching grammer, spelling, sentence writing, paragraph drafting, outlining, drafting, revising, the use of peer and teacher evaluation, and the use of drills and exercises. The English teacher specifically stressed the developing of student *enjoyment* of writing tasks as a strategy to promote learning and writing proficiency.

Discussion: Teacher and student views of the purpose of writing

Most teachers (excepting the English and ESL teachers) appear to use writing as a tool for recording important facts and items of information related to their subjects, so that they can be mastered, learned, and reproduced as required.

The English teacher views writing in a different light — "as a thinking process" and as a "form of self-understanding". The implication here is that education is not so much to do with absorbing a body of knowledge in order to reproduce it in an identical form as it is to do with thinking about new information in order to reconstruct it and integrate it with the students' developing perceptions and understanding of the world and how it relates to them. The English teacher states that 'all writing requires student involvement in order to be successful' implying that writing can be an activity which mediates between new information and knowledge or experience that they already possess.

While the teachers appear to have fairly precise and well-articulated views of the role of writing in their classes — as a record of information taught and as evidence of information acquired on the one hand and as an instrument of learning on the other — the students appear to have no coherent or well-articulated parallel opinion or understanding.

Most students had a vague notion that writing tasks had something to do with learning but were unable to articulate the kind of learning that was supposed to take place or what exactly was supposed to be learned by writing. Several associated writing with having a record of the facts you "have to learn"; others associated writing with being tested or assessed for mastery of certain information or for passing examinations. One student mentioned that teachers set writing tasks 'to make us learn so we can graduate and have jobs'. None echoed those teachers' views that writing aided organizing information, or reflected a thinking process or was a means of striving towards self-understanding or promoted language skills necessary for performing assignments successfully. The fact that there appears to be little consciousness on the part of the students of any clear purpose behind learning to write may contribute to their relative lack of success with writing. With no awareness of the purpose underlying an assignment or the supposed advantages to be gained from it, a student may be inhibited or even prevented from adopting appropriate strategies for its successful execution or even from being motivated to perform the task well at all.

It would seem indeed that, given the vast array of claims on class time in junior high school, teachers must make choices. Teachers who "have a curriculum to get through" will understandably tend to reduce to a minimum the types of tasks on which students are perceived to perform poorly. This is especially likely where the teacher feels that the skills in which the students are deficient cannot be readily supplied or are seen as not being the primary responsibility of that teacher. Writing tasks fall into this category. Students are perceived to be lacking in general writing ability by content teachers (Math, Social Studies), who, with some justification, do not view the remedying of that deficiency as their *primary* responsibility, even if they had the time and the expertise to do so. These content teachers appear to respond to this dilemma by reducing the variety of writing tasks they require of the students to that narrow range which they can perform without additional instruction, such as copying, or which students can be trained to produce tolerably well and with a minimum of loss of time by following a pattern, such as writing brief lab reports or completing blanks on worksheets.

Acknowledgments

We are indebted to Ernest Spencer of the Scottish Centre for Research in Education for his extensive research study of writing in Scottish schools reported in *Writing Matters Across the Curriculum*, Hodder and Stoughton 1983. Their study influenced our own investigation profoundly and provided us with the questions used in the student interviews and in the teacher questionnaires. The study presented here is part of a more extensive study of the role of English in education in the Eastern Arctic of Canada currently being undertaken by Ronald Mackay.

References

Heyman, Richard D. Language use and school performance in a native classroom. Canadian Journal of Native Studies. Vol. 4, No. 1, 1984, pp. 11-28.

Learning, Tradition and Change in the Northwest Territories. Report of the Special Committee on Education, Legislative Assembly of the Northwest Territories, Yellowknife, 1982.

Oller, J.W. Jr. Forward In Virginia Streiff, Reading Comprehension and Language Proficiency among Eskimo Children, Amo, N.Y. 1978.

Shouldice, Michael. Making education work for Inuit in the modern world. Inuktitut Magazine Summer 1986, pp. 56-68. Indian and Northern Affairs Canada.

THE IMPACT OF THE SNOWMOBILE IN MAKKOVIK, LABRADOR

Violet Ford

Mount St. Vincent University, Halifax, N.S. B3M 2J6

Level: Bachelor's

Abstract

The paper attempts to present the similarities of dependence on the reindeer and dog teams of northeastern Finland and northern Labrador respectively, and adjustments with the introduction of the snowmobile to both societies. The statements I make are from generalizations and observations, of being born and raised in a northern Labrador community; also from a few interviews with local trappers and hunters. The information on northeastern Finland is from "The Snowmobile Revolution", Technology and Social Change in the Arctic, by Dr. J. Pelto.

Since the arrival of the snowmobile in both regions (about 1961-62) there have been changes in the economic situation in households. Social interaction patterns, within and between communities, have been altered. Increased travel has resulted. Trapline patterns of trappers have been affected. The greatest impact may have been on the annual caribou hunt, attracting people from other southern Labrador communities, giving them the ability to travel far distances to the northern caribou herd. The snowmobile changed the role of women regarding the performance of tasks normally done by men; for example in the hauling of firewood, on a separate snowmobile and sled. The snowmobile, according to some older residents, has increased the amount of spare time people have on their hands during the long winter months.

The snowmobile has created advantages and disadvantages, as any new technology would.

Key words: Snowmobile, Labrador, technology impact, dog teams, reindeer .

Résumé

L'auteure s'efforce de mettre en relief la dépendance similaire des collectivités du Nord-Est de la Finlande et du Nord du Labrador à l'égard, respectivement, du renne et de l'attelage de chiens, et les modifications provoquées par l'introduction de la motoneige. L'auteure, née et élevée dans le Nord du Labrador, a généralisé ses propres observations et a interrogé des trappeurs et des chasseurs de cette région, ce qui lui a permis d'élaborer ses conclusions. Elle a tiré les renseignements concernant la situation dans le Nord-Est de la Finlande de l'ouvrage de J. Pelto: «The Snowmobile Revolution, Technology and Social Change in the Arctic».

L'arrivée de la motoneige dans ces deux régions, vers 1961-1962, a modifié la condition économique des ménages et les patterns de contact social, tant au sein des collectivités qu'entre celles-ci. La diffusion de la motoneige a multiplié les déplacements, et les trappeurs ont changé l'organisation de leurs rondes de piégeage. Mais son incidence la plus forte se produit peut-être lors de la chasse au caribou, car les chasseurs appartenant aux collectivités du Sud du Labrador ont ainsi la possibilité d'atteindre la harde lointaine des caribous du Nord. La motoneige a également modifié le rôle des femmes, qui accomplissent maintenant des tâches normalement assumées par les hommes, par exemple le transport du bois de chauffage, grâce à un traîneau tiré par une autre motoneige. Selon certains Autochtones âgés, la motoneige a accru le temps libre dont les gens disposent au cours des longs mois d'hiver.

Comme toute nouveauté technique, la motoneige a eu ainsi des effets favorables et défavorables.

Mots-clés: Motoneige, Labrador, effets technologiques, attelage de chiens, renne.

Through this paper I have attempted to provide information on the similarities in effects of the introduction of the snowmobile in northeast Finland, and northern Labrador, and the impacts on the reindeer and dog teams respectively.

I have no specific data on which to make this comparison. It is mainly based on my personal experience of being born and raised in a northern Labrador community. The information of Finland is from "The Snowmobile Revolution" *Technology & Social Change in the Arctic* by Dr. J. Pelto (1973). The statements made are from generalizations and observations. However, some information was gathered through interviews with local trappers, and hunters.

I feel that it is important to present a background of northern Labrador, before discussing the effects of the snowmobile.

The people of northern Labrador are mainly of European, Indian, or Inuit ancestry, or a combination of those. Their economy is based on the commercial fishery, along with hunting and trapping. The fishery has grown significantly in the past 10 to 15 years, with the setting up of new fish-plants, and the use of bigger boats. The families at one time lived around bays and coves.

The weather generally includes fairly long winters and short warm summers. The main mode of ground transportation in winter, to get from place to place, was by dog team and dogs were also used to gather wood and to hunt. Things have changed since then and now people depend heavily on the snowmobile in winter. It has had a powerful impact with significant consequences. Northern Labrador depended as much on dog teams, as the Skolts of Finland depended on reindeer. Dog teams were needed not only as a form of transportation, but also for lost drivers to find their way back to a community during a storm. This can't be done with a snowmobile.

Food for the dogs mainly consisted of seal meat, fish, cornmeal, or a combination of all three. Preparing the meal demanded time, and only a small expense.

Dog teams weren't seen as the most convenient when someone needed to be rushed to a nursing station. They were used to carry mail which would take weeks to get to all the communities in northern Labrador. Most people had no fear of dogs, but from time to time, someone (usually a child) had the awful experience of being bitten, on occasion, fatally. Dogs were used to get firewood. They were especially useful for this task before spring breakup. This was a time when the men gathered the wood needed for the spring, summer, and fall. This is similar to the Skolts of Finland, in their use of reindeer as Pelto (1973) states.

> "In late winter, before the spring breakup, it was essential to gather large supplies for the summer. Generally houses did not need to be heated during the summertime, but cooking still required a considerable fuel supply . . ."[1]

Similar to the Skolts, we celebrated social gatherings.

> "The great emphasis on mobility as the key to successful adaptation was expressed in reindeer races and other contents . . ."[2]

People from northern Labrador would gather in one community for dog team races on Easter Monday. This has always been a special day of the year, when people gather to socialize and take part in other sports events. This still continues at present. During the dog team races, traditionally and today, large prizes are given, to attract more drivers, and to encourage younger drivers to participate.

Similarly, the Skolts use reindeer for their races.

> ". . . people were gathered for the traditional reindeer races. This turned out to be the last reindeer races . . . snowmobiling had captured their interest . . ."[3]

At present, snowmobile races follow the, once major, dog team event. Women take part in the snowmobile races, and snowmobile races for children are included.

Another similarity between us and the Skolts is the role and effect the weather had on how fast or slow the drivers could reach their destination.

> ". . . the onset of a winter blizzard could slow their travel so that the trip would end up taking five days. . ."[4]

The dog team was a means of survival for us. It was also a means of social communication as men would gather at each other's houses where much of their conversation would be centered around their dogteam, during the winter nights.

As mentioned before, the task of providing the dog teams with food was time consuming. It also took time to harness the dogs, before going on a trip. This type of problem was similar to the Skolts, with the reindeer.

> ". . . it often took a herdsman an hour or two to capture "his motor" for harnessing and hitching up and unhitching . . ."[5]

The first snowmobiles arrived in northern Labrador about the same time as in Finland, which was about 1961. The first snowmobile in our community was for the nurses' station. This made sense, as it would be of use to get patients to the station more quickly, or the nurses could get to a home in a very short length of time. Soon, people were aware of the advantage of the snowmobile, and those who could easily afford it, quickly obtained one.

The snowmobile has had an impact on the way trapping and hunting activities are carried out.

Trappers, who once had to spend weeks on end attending the traplines, can now limit the amount of time and can also increase the number of traplines. It hasn't been documented whether this had an effect on the success of trapping in any particular area.

With regard to the annual caribou hunt, I would say, and I'm sure most people would agree, the snowmobile has had the greatest impact. Where once hunters could only go short distances, for example a 50 mile radius, they can now travel up to 500 miles away. They can now hunt the George River caribou herd, (the largest caribou herd in the world). Now caribou hunters from southern Labrador can travel to the herd in a short time (6 to 7 days). This machine has enabled the hunters to make several trips and to carry bigger loads of caribou.

Without the snowmobile, the Labrador Inuit Development Corporation's newly introduced commercial caribou hunt may not have been possible.

Caribou hunters can drive up quickly to a herd and shoot before the herd has had time to disperse. The use of the snowmobile helps the hunter to cover a wide range of territory.

This has caused extra wear and tear on the machine, creating a new expense, for new parts, repairs, etc.

Pelto (1973), in his book, mentions economic impacts, experienced by us in the northern Labrador communities. He states that:

> "thirteen households maintained more than one snowmobile . . . a brisk business in used snowmobiles was developing . . ."[6]

We began to have more than one snowmobile per household, which may have indicated a new system of stratification (on a small scale). Those who couldn't afford a new snowmobile patiently waited for a rumour that someone would be selling theirs for a half decent price. People now have to set aside extra savings from their summer employment to obtain one. This explains the extra attention given to the management of their financial budget.

Maintaining a snowmobile is also part of having one. People in our community (who don't have the skills) rely on one or two people to repair their machines. As mentioned by Pelto (1973):

> "there are those special people to whom friends, neighbours, and kin can turn for technical advice . . ."[7]

When travelling in Labrador, hunters always carry spare parts.

The social impacts of the snowmobile in Labrador, and Finland have been much the same.

> ". . . the increased speed with which people can get from one place to another has increased the rate of social interaction . . . has brought about changes in the scheduling . . . of many group activities . . ."[8]

In Labrador, people from nearby communities visit each other more often, and can travel as far as 100 miles away for a relative's house party, or for weekend soccer matches in a community, on harbour ice. The snowmobile has contributed much to a new form of recreation, with camping trips and boil-ups (having a hot lunch outside).

The role of women has changed somewhat, since the introduction of the snowmobile. They now attend traplines with their husbands, and help out with the hauling of supplies of firewood, usually on a separate snowmobile. As well, to some extent, it has increased the amount of leisure time available.

As seen through this paper, there are advantages and disadvantages of the snowmobile. It is difficult to weigh one against the other. The Inuit have been tremendously successful in adapting to this machine, by maintaining it and handling the cost, most times without their own language to assist them.

Some still have more faith in the dogteam for various reasons. Whatever way one looks at it, when new technology is introduced it has heavy consequences for the society as a whole. Finland and Labrador were no exceptions.

References

1. Dr. J. Pelto, The Snowmobile Revolution, 2727 Sandhill Road, Preslo Par, California, Cummings Publishing Company Inc. Pg. 57.
2. Ibid, pg. 54.
3. Ibid, pg. 70.
4. Ibid, pg. 61.
5. Ibid, pg. 65.
6. Ibid, pg. 75.
7. Ibid, pg. 138.

SYSTÈME CIRCUMPOLAIRE ET DÉSARMEMENT RÉGIONAL

Michel Frédérick

Science politique, Université Laval, Ste-Foy, Québec G1K 7P4
**Maître en droit public (Ottawa) et en science politique (Laval); candidat au doctorat en science politique à l'université Laval*

Niveau: Doctorat

Résumé

Les régions arctiques ont toujours échappé aux grands courants qui ont marqué l'avènement du désarmement régional et son intégration progressive au processus du désarmement global au cours des trente dernières années. Aujourd'hui toutefois, cette situation risque de changer en raison, d'une part, de l'émergence d'un système régional circumpolaire et, d'autre part, de la militarisation et de la nucléarisation toujours croissantes de ces régions. Dans ce contexte, il importe de se demander jusqu'à quel point la création d'une zone exempte d'armes nucléaires (ZEAN) dans les régions arctiques peut s'avérer une mesure réaliste et un instrument efficace de désarmement régional. Selon nous, cette question bi-dimensionnelle (opportunité et adéquation) ne peut finalement trouver de réponse satisfaisante que dans une analyse de la valeur géostratégique des régions arctiques et des intérêts que les pays circumpolaires y possèdent.

Mots-clés: Arctique, désarmement, zone exempte d'armes nucléaires, géostratégie, installations militaires.

Abstract

Since the inception of the regional disarmament process some thirty years ago, the arctic regions have rarely been the subject of a regional disarmament proposal. That situation could change however, taking into account the emergence of a circumpolar regional system and the ever increasing military and nuclear buildup in these regions. Given that fact, it is

our intention to examine if the idea of an arctic nuclear free zone can be shown to be a realistic and effective disarmament measure. In our view, only a careful analysis on the one hand of the geostrategic importance of the area and on the other hand of the various arctic interests of the circumpolar countries can enable us to decide on this delicate matter.

Key words: Arctic, disarmament, nuclear free zone, geostrategy, military installations.

Introduction

Au cours des trente dernières années, l'«approche régionale» a été l'une des méthodes les plus utilisées pour aborder le problème de la limitation et du contrôle des armements. Dans ce cadre, le concept de zone exempte d'armes nucléaires (ZEAN) a sans doute été celui qui a frappé le plus l'imagination des pacifistes légitimement préoccupés par la crainte de voir certaines puissances régionales fabriquer ou acquérir des armes nucléaires ou autoriser le déploiement ou l'essai de telles armes sur leur territoire. Des propositions portant création de ZEAN ont ainsi surgi d'un nombre impressionnant de régions, comme le Moyen-Orient, les Balkans, l'Europe septentrionale, l'Amérique latine, l'Afrique, l'Asie méridionale et le Pacifique Sud. L'idée sous-jacente de ces propositions était simple: enserrer la paix dans des frontières à l'abri de la rivalité déstabilisante des deux superpuissances en créant des îlots non nucléaires.

Le large écho qu'a connu cette idée de créer des ZEAN n'a toutefois pas été répercuté au sein des régions arctiques. Celles-ci ont en effet été tenues à l'écart de ce vaste courant. Cela n'étonne point: ces régions ont toujours été considérées comme une contrée éloignée, isolée et inhospitalière, sise à la périphérie d'un très petit nombre d'États. En outre, les deux superpuissances s'y livrent à une intense activité militaire: la course aux missiles balistiques intercontinentaux qui sévit depuis le tournant des années 60 et surtout l'avènement d'une force stabilisatrice de seconde frappe embarquée à bord de sous-marins nucléaires lance-missiles balistiques capables de naviguer sous la calotte polaire ont en effet complètement modifié l'importance géostratégique des régions arctiques, si bien que certaines parties de celles-ci comptent aujourd'hui parmi les plus militarisées au monde. On retrouve notamment, dans les zones arctiques américaine et/ou soviétique, toute la panoplie existante d'armes nucléaires tactiques et stratégiques, des super-missiles intercontinentaux mirvés jusqu'aux simples obus nucléaires, en passant par les missiles de croisière et les torpilles atomiques.

Devant cette militarisation toujours croissante des régions arctiques et devant les progrès que le régionalisme a réussi à marquer au sein du monde circumpolaire au cours de la dernière décennie (notamment depuis l'avènement de la Conférence inuit circumpolaire), il est d'intérêt selon nous de procéder à l'examen du contenu que serait susceptible de véhiculer un processus régional de limitation et de contrôle des armements dans l'Arctique. À cet égard, nous avons choisi de nous tourner vers le concept de ZEAN et d'en déterminer l'applicabilité aux régions arctiques. Nous tenterons donc de répondre à la question suivante: compte tenu de la valeur stratégique des régions arctiques et de la militarisation qui y a cours, jusqu'à quel point la création d'une ZEAN dans ces régions peut-elle s'avérer, d'une part, une mesure réaliste et, d'autre part, un instrument efficace de désarmement régional?

Qu'est-ce qu'une ZEAN?

La résolution 3472 B adoptée le 11 décembre 1975 par l'Assemblée générale des Nations Unies fournit la définition suivante de la notion de ZEAN:

> Par «zone exempte d'armes nucléaires», il faut entendre en règle générale toute zone reconnue comme telle par l'Assemblée générale des Nations Unies que tel ou tel groupe d'États agissant dans le libre exercice de leur souveraineté a établie en vertu d'un traité ou d'une convention aux termes duquel ou de laquelle:
>
> a) Est défini le statut d'absence totale d'armes nucléaires auquel la zone sera soumise, avec la marche à suivre pour délimiter la zone;
>
> b) Est établi un système international de vérification et de contrôle en vue de garantir le respect des obligations découlant de ce statut.

Cette définition identifie et regroupe cinq éléments qui énoncent clairement les grands principes devant, en règle générale, régir la création des ZEAN. On y reconnaît en effet, premièrement, que l'initiative de la création d'une ZEAN doit venir des États dont les territoires seront compris dans la zone; deuxièmement, que l'instrument portant création de la zone doit être une convention ou un traité librement conclu; troisièmement, que le statut de la zone doit être caractérisé par une absence totale d'armes nucléaires; quatrièmement, qu'un système international de vérification et de contrôle garantissant le respect des obligations découlant de ce statut doit être du même coup mis en place; et cinquièmement, que la ZEAN ainsi créée soit reconnue par l'Assemblée générale des Nations Unies. Cette définition (calquée, soulignons-le, sur le Traité de Tlatelolco de 1967 portant création d'une ZEAN en Amérique latine) trace une démarche relativement complexe qui suppose un certain degré de cohésion régionale, particulièrement en ce qui touche à la perception que peuvent avoir les États de l'équilibre des forces ou des sources de tension en fonction desquelles ils élaborent les conditions politiques et militaires de leur sécurité. Par ailleurs, ces cinq éléments constitutifs d'une ZEAN laissent aux États concernés une grande latitude d'appréciation quant à l'étendue du cadre géographique propice à la dénucléarisation et quant au contrôle du respect de cette dénucléarisation.

Naturellement, la viabilité d'une ZEAN va dépendre directement de la façon dont les États compris dans la zone et les États nucléarisés qui lui sont extérieurs choisiront de s'acquitter des obligations que la création de cette ZEAN leur aura imputées. Pour les États appartenant à une ZEAN, ces obligations s'énoncent dans une triple interdiction:

— interdiction de la mise au point, de l'essai ou de la production par quelque moyen que ce soit de tous les dispositifs explosifs nucléaires, directement ou indirectement, pour leur compte ou pour celui d'un tiers, ou de toute autre manière;

— interdiction d'acquérir, détenir ou recevoir des armes nucléaires, de quelque façon que ce soit directement ou indirectement, par eux-mêmes, par qui que ce soit pour leur compte ou de toute autre manière à l'intérieur ou à l'extérieur de la zone;

— interdiction et prévention, dans les territoires relevant de leur juridiction de l'installation, la mise en place, l'emmagasinage et le stockage d'armes nucléaires lorsque ces armes sont sous le contrôle d'États situés en dehors de ces zones.

Comme on peut le voir, ces obligations sont très étendues et elles vont même plus loin que ne le fait le Traité sur la non prolifération nucléaire puisqu'elles interdisent aux États nucléarisés toute assise territoriale à leurs armes atomiques au sein de la zone. Par contre, elles laissent en plan toute la question du libre exercice de la technologie nucléaire (la nécessité technologique, par exemple, de procéder à des explosions nucléaires pacifiques) ainsi que la question fort controversée du transport et du transit des armes nucléaires au sein de la ZEAN. Sur ce point, il est clair qu'une interdiction de transit aurait pour effet de prévenir un détournement de l'objet même du traité portant création de la ZEAN. D'autre part, il faut reconnaître qu'une telle interdiction poserait du même coup de sérieux problèmes de compatibilité avec le droit international particulièrement s'il était question d'assujettir aux dispositions du traité des sections de la haute mer ou de l'espace aérien international.

Quant aux obligations incombant aux États dotés d'armes nucléaires et situés à l'extérieur d'une ZEAN, la même résolution 3472B de l'Assemblée générale les décrit en ces termes:

a) Respecter tous les aspects du statut d'absence totale d'armes nucléaires défini dans le traité ou la convention portant création de la zone;

b) S'abstenir de contribuer de quelque manière que ce soit à l'accomplissement, dans les territoires faisant partie de la zone, d'actes impliquant une violation du traité ou de la convention susmentionnée;

c) S'abstenir d'utiliser ou de menacer d'utiliser des armes nucléaires contre les États qui font partie de la zone.

Les États dotés d'armes nucléaires seraient donc notamment tenus de s'engager à ne pas installer, mettre en place ou stocker d'armes nucléaires dans la zone ou, dans le cas où cela aurait été fait dans le passé, à retirer immédiatement ces armes de la zone; à donner l'assurance, si ces États possèdent des bases militaires dans la zone, que ces bases ne contiennent aucune arme nucléaire; et à ne pas fournir aux États compris dans la zone une aide quelconque pour la mise au point, la fabrication ou l'acquisition d'armes nucléaires. La coopération des États dotés d'armes nucléaires apparaît donc comme essentielle au renforcement de l'efficacité d'une ZEAN.

Les ZEAN existantes

Dans un premier temps, même s'ils ne correspondent pas au portrait-type d'une ZEAN, il faut selon nous considérer comme formant de telles zones les vastes territoires-frontières visés par les instruments internationaux de non nucléarisation que sont le Traité sur l'Antarctique (1961), le Traité sur l'espace extra-atmosphérique (1967) et le Traité sur les grands fonds marins (1971). En effet, ces territoires-frontières, généralement inhabités et sur lesquels aucun pays n'exerce de souveraineté nationale, ont été réservés en vertu de ces traités aux activités de nature strictement pacifique. Les armes nucléaires y sont par conséquent frappées d'interdiction. Les États signataires assument d'ailleurs à cet égard des obligations dont la portée n'est pas sans nous rappeler celle des obligations découlant de l'instauration d'une ZEAN.

Dans un second temps, il nous faut bien sûr nous pencher sur les deux seules «véritables» ZEAN à avoir vu le jour jusqu'ici, soit la ZEAN Amérique latine et la ZEAN Pacifique Sud. Conclus respectivement en 1967 et 1985, les traités portant création de ces zones sont le fruit de négociations amorcées par les États régionaux en réponse à des événements qui avaient suscité chez eux la crainte de voir leur région subir les conséquences de la convoitise des grandes puissances nucléarisées (crise des missiles de Cuba en Amérique latine et poursuite des essais nucléaires français dans le Pacifique Sud). Ces deux traités partagent d'importantes caractéristiques: ils embrassent tous deux de vastes espaces géographiques, dont des territoires densément peuplés; ils perpétuent la dénucléarisation *de facto* qui existait au sein de ces régions avant la signature des traités; ils vont au-delà des dispositions du Traité sur la non prolifération en interdisant non seulement l'acquisition d'armes nucléaires mais aussi l'entreposage de ces armes dans la zone par les puissances extérieures; ils respectent les dispositions du droit international touchant la liberté de navigation en haute mer, le droit de survol et le droit de passage inoffensif ou en transit dans les eaux territoriales (l'accès aux ports et aux aéroports étant cependant laissé à la discrétion des États); et ils sont accompagnés de protocoles additionnels ouverts à la signature des États extérieurs à la zone, par lesquels ceux-ci peuvent s'engager à respecter le traité portant création de la ZEAN.

Avant que ne soit conclu, en août 1985, le Traité instaurant une ZEAN dans le Pacifique Sud, la ZEAN Amérique latine a été pendant près de vingt ans un succès isolé, un modèle dont on ne pouvait trouver d'imitation. En dépit du prestige découlant de son unicité, la ZEAN Amérique latine symbolisait également l'échec du désarmement régional: elle constituait en quelque sorte l'exception confirmant la règle. Car il y a eu au fil des ans, au sein de divers forums internationaux et régionaux, plusieurs propositions portant création de ZEAN. Mais parce que ces propositions avaient trait à des régions où des armes nucléaires étaient déjà stationnées et qu'elles impliquaient par conséquent le retrait de ces armes (comme en Europe centrale, dans les Balkans, en Méditerranée et dans l'océan Indien) ou parce qu'elles avaient trait à des régions où la fabrication (par exemple au Moyen-Orient et en Afrique australe) ou encore l'introduction (par exemple en Europe septentrionale) d'armes nucléaires en cas de conflit y demeurait possible, aucune de ces propositions n'ont donné lieu à des négociations soutenues qui auraient pu présager de l'éventuelle création d'autres ZEAN. Pour tous les pays concernés, et plus spécialement pour les grandes puissances nucléarisées, il y a toujours la crainte que l'instauration d'une ZEAN n'entraîne pour eux tous, ou pis encore pour un seul d'entre eux, l'abandon d'une doctrine stratégique jugée vitale pour leur sécurité: «. . . la réticence des États à conclure des accords de désarmement

n'est jamais que la conséquence de l'enjeu qu'ils représentent, enjeu où dominent les conflits de puissance tant universels qu'intra-régionaux» (Szurek, 1984). Ce sont donc les intérêts stratégiques des pays concernés et aussi, il faut en convenir, ceux des grandes puissances nucléarisées, qui vont finalement décider de l'opportunité de la création d'une ZEAN dans une région donnée. Par conséquent, au sein du monde circumpolaire où se confrontent, tant géographiquement que militairement, les États-Unis et l'Union soviétique, il y a certes lieu de s'interroger sur l'opportunité et l'adéquation de recourir au concept de ZEAN pour aborder la question fort complexe du désarmement arctique.

La valeur stratégique des régions arctiques

L'approche régionale permet d'envisager des mesures de désarmement au niveau même où se situent les préoccupations de sécurité des États. Or, comme on l'a vu, ces préoccupations de sécurité se posent toujours, lorsqu'il est question de créer une ZEAN, en rapport direct avec la valeur stratégique intrinsèque et extrinsèque de la région concernée. C'est pourquoi nous examinerons maintenant la valeur stratégique des régions arctiques.

Depuis la polarisation des rapports militaires qui a suivi la fin de la Seconde Guerre mondiale, les deux superpuissances ont attribué aux régions arctiques un rôle actif dans leur stratégie militaire globale. Ce rôle a, depuis, toujours été rehaussé par les progrès technologiques qui ont marqué pendant cette période le domaine de l'armement: arrivée des fusées intercontinentales à trajectoire elliptique dont le plan passe par le pôle; avènement des missiles de croisière aéroportés qui redonnent une raison d'être aux bombardiers stratégiques et une nouvelle vocation aux couloirs aériens arctiques; et, surtout, le développement d'une force nucléaire stabilisatrice de seconde frappe, embarquée à bord de sous-marins nucléaires lance-missiles balistiques (SNLE) capables de naviguer sous la calotte polaire et de faire surface au travers les lucarnes et des polynies qui s'y forment. Tout cela, couplé au déterminisme géographique qui fait des régions arctiques le plus court chemin entre les deux superpuissances, a donc directement accru la valeur de ces régions comme théâtre d'opération stratégique pour les États-Unis et leurs alliés arctiques de l'OTAN (Canada, Danemark et Norvège) et pour l'Union soviétique qui compte beaucoup sur elles pour compenser le désavantage qu'elle accuse aux États-Unis au chapitre des bases militaires alliées sises à proximité du «sanctuaire» adverse.

Conséquemment, les territoires arctiques des pays circumpolaires ont été perçus comme les meilleurs tremplins ou encore comme des escales vitales pour les forces aériennes d'attaque ou d'interception de l'OTAN et de l'Union soviétique. De part et d'autre, l'on y a construit d'importants aérodromes militaires ainsi que des réseaux de stations-radars sophistiqués qui scrutent le ciel arctique en permanence afin d'y détecter tout indice d'une attaque lancée, à travers le Pôle, soit par voie aérienne (bombardiers et missiles de croisière) soit par voie extra-atmosphérique (missiles balistiques intercontinentaux et missiles balistiques embarqués). D'autre part, plusieurs des vastes étendues d'eau arctique sont rapidement devenues l'enjeu d'une lutte invisible incessante visant à s'assurer un contrôle efficace et, dans la mesure du possible, permanent de ces zones maritimes. Dans ce cadre stratégique, l'Union soviétique a fait de la mer de Barents le lieu d'évolution naturelle de la plus puissante de ses quatre grandes flottes, la flotte du Nord (Häggman, 1981). La raison pour cela est que cette importante mer constitue pour l'Union soviétique *sa seule voie d'accès directe et permanente* (c'est-à-dire libre de glace à l'année) aux océans Arctique et Atlantique. En effet, la lecture des cartes nous apprend que les quatre façades maritimes de l'Union soviétique sont non seulement très isolées les unes des autres mais également plus ou moins fermées par les forces de l'OTAN ou celles d'autres alliés des États-Unis. Il n'y a donc que la façade arctique qui jouit d'une situation favorable, principalement à l'ouest alors que la péninsule de Kola offre à la marine soviétique des ports libres de glace à l'année, en raison du prolongement du Gulf Stream jusqu'en mer de Barents, ainsi que des bases pratiquement inattaquables, pour des raisons géologiques, autrement qu'avec des moyens nucléaires (Klenberg, 1968). De plus, cette péninsule présente l'avantage d'être située loin du périmètre de défense de l'OTAN dans ce secteur, qui est établi beaucoup plus au sud entre le 60^{e} et le 65^{e} parallèle. Sachant tous ces faits, il nous est plus facile de comprendre la vision essentiellement stratégique que possède l'Union soviétique des régions arctiques, vision que partagent également les pays circumpolaires membres de l'OTAN.

En effet, eux aussi sont très présents dans les mers épicontinentales arctiques, car ils voient dans ces régions un théâtre d'opération vital à l'élaboration de leur stratégie militaire globale dans l'Atlantique Nord. Il est d'ores et déjà acquis au sein de l'OTAN que la maîtrise de certaines étendues d'eau périphériques comme la mer de Norvège et la mer du Groënland s'avérerait déterminante, en cas de conflit, quant à la capacité de l'OTAN d'assurer le soutien logistique nécessaire à la défense continentale de l'Europe de l'Ouest et au maintien des liaisons maritimes dans l'océan Atlantique entre l'Amérique, l'Europe et le Moyen-Orient (Bjol, 1983). Aussi, les pays membres de l'OTAN ont-ils installé à l'embouchure atlantique des mers arctiques un périmètre de défense appelé «périmètre GIRU» qui utilise à son avantage le goulot d'étranglement naturel formé des eaux comprises entre le Groënland à l'ouest, l'Islande au centre et le Royaume-Uni à l'est (d'où le sigle GIRU), au travers duquel devrait inévitablement passer la formidable flotte soviétique du Nord pour gagner l'océan Atlantique. Selon certaines études indépendantes, l'efficacité technique de ce périmètre de défense serait déjà très grande particulièrement à l'endroit des sous-marins qui se verraient nier, à toutes fins utiles, leurs deux atouts majeurs que sont la mobilité et l'indétectabilité au moment de pénétrer dans l'Atlantique Nord (Ostreng, 1977 et Gunnarsson, 1982). Naturellement, une telle efficacité contribue par ricochet à accroître l'importance militaire des mers arctiques situées en deçà du périmètre de défense et, partant, à accroître la perception stratégique que les pays circumpolaires entretiennent à l'égard des régions arctiques dans leur ensemble. Ainsi, l'Union soviétique pourrait-elle décider, si ce n'est déjà fait (Arkin et Fieldhouse, 1985), de déployer désormais de façon permanente une partie de ses SNLE non plus dans l'Atlantique Nord, mais dans l'océan Arctique lui-même ou ses mers épicontinentales. En effet, «the Arctic Ocean has become for the Soviets a realistic deployment alternative to the Atlantic and Pacific Oceans» (Ostreng, 1977). En fait, d'un point

relativement central comme la mer de Laptev, les nouvelles générations de SNLE soviétiques peuvent frapper non seulement aux États-Unis, mais également en Chine et en Europe occidentale. Bien sûr, la navigation sous les mers arctiques est nettement plus périlleuse que sous des mers plus tempérées et le ravitaillement y est plus problématique. Par contre, il faut souligner que les rudes conditions climatiques qui prévalent dans les mers polaires y rendent la lutte anti-sous-marins beaucoup plus difficile, si bien que ces régions offrent finalement un théâtre d'opération beaucoup plus sûr pour les SNLE (Ostreng, 1977 et Daniels, 1984). Ce qui à nouveau accroît la valeur stratégique que prennent les régions arctiques aux yeux des acteurs militaires présents puisqu'elles leur permettent somme toute, tant du côté de l'OTAN que de l'Union soviétique, de conserver à leur arsenal nucléaire de seconde frappe embarqué, une crédibilité réelle, redoutable et dissuasive.

La nucléarisation des régions arctiques

Résultat direct de l'affrontement OTAN/Union soviétique qui a cours depuis la fin de la Seconde Guerre mondiale, la militarisation des régions arctiques a atteint un point tel que ces régions constituent désormais, après l'Europe centrale, la zone la plus militarisée de la planète. Cela a de quoi inquiéter le plus optimiste des habitants circumpolaires compte tenu que cette militarisation est en outre intrinsèquement liée à l'articulation des stratégies nucléaires des deux superpuissances. La création d'une ZEAN au sein des régions arctiques emporterait donc pour les États-Unis et l'Union soviétique d'importants sacrifices stratégiques. Pour mesurer l'ampleur de ces sacrifices, voici une brève description de la nucléarisation croissante que connaissent ces régions depuis une quinzaine d'années.

L'électronique joue aujourd'hui un rôle de premier plan dans la conduite des activités militaires. Nous retrouvons par conséquent, disséminés un peu partout dans les régions arctiques, toute une panoplie de systèmes électroniques vitaux au maintien de la capacité de frappe et de dissuasion des arsenaux des pays circumpolaires de l'OTAN et de l'Union soviétique: stations d'aide à la navigation sous-marine dans les mers arctiques, qui permettent aux SNLE de programmer avec précision les coordonnées d'attaque des missiles nucléaires qu'ils transportent; installations de télécommunications destinées à assurer une liaison fiable et permanente entre les centres de commandement et les unités des grandes flottes où qu'elles soient; réseaux perfectionnés de détection sous-marine servant à suivre les déplacements des sous-marins naviguant sous les mers de Barents, du Groënland, de Norvège et de Bering; réseaux avancés de détection aérienne et spatiale chargés de repérer les aéronefs conventionnels (bombardiers stratégiques et chasseurs), les missiles de croisière largués au-dessus des régions polaires et les missiles balistiques intercontinentaux ou embarqués.

Au chapitre des bases militaires, il faut d'abord parler, en ce qui concerne l'Union soviétique, de la péninsule de Kola qui constitue, avec ses vastes installations navales, aériennes et terrestres, sans doute l'une des zones les plus densément militarisées au monde. On y retrouve en effet près de 40 000 soldats équipés des armes les plus modernes: plus de 600 blindés, de l'artillerie lourde à capacité conventionnelle ou nucléaire (obus de 2 à 5 KT chacun), et de nombreuses batteries de missiles sol-air ou sol-sol (antichars) à capacité conventionnelle ou nucléaire (ogives jusqu'à 200 KT). Tous ces soldats ont notamment pour mission de protéger la plus importante base aéronavale de l'Union soviétique, dont l'ampleur témoigne de la valeur stratégique qu'ils accordent à cette façade maritime et aux eaux arctiques avoisinantes. En effet, c'est à Severomorsk dans le nord de cette péninsule de Kola que les Soviétiques ont établi le quartier général de la plus puissante et de la plus moderne de leur quatre flottes: la flotte du Nord. Celle-ci comprend, en fait de bâtiments de surface, un porte-avions; 13 croiseurs armés de missiles antisurface conventionnels ou de croisière (ogives de 200 à 350 KT) et de missiles antiaériens; 20 destroyers polyvalents armés de missiles mer-mer et mer-air à tête conventionnelle ou nucléaire (1 à 5 KT); 47 frégates et corvettes adaptées à la défense antisous-marin et antiaérienne (grenades ou missiles conventionnels ou nucléaires); 120 patrouilleurs et vedettes lance-missiles; 83 dragueurs de mines et 2 mouilleurs de mines (conventionnelles ou nucléaires de 5 à 20 KT). Ces bâtiments ont comme principaux ports d'attache les ports de Pechenga, de Mourmansk et de Severomorsk en mer de Barents. La flotte du Nord comprend également 180 sous-marins, soit environ 45% de tous les sous-marins soviétiques. Sur ces 180 sous-marins, 39 sont des SNLE qui transportent à eux seuls les deux tiers de tout l'arsenal nucléaire soviétique embarqué soit plus de 600 missiles balistiques. Rappelons que grâce à la portée de leurs missiles balistiques, ces sous-marins se retrouvent en position de tir dès la sortie de leurs bases en mer de Barents, donc loin des défenses occidentales et sous la protection des forces aéronavales soviétiques. Quant aux quelque 140 autres sous-marins qui complètent cette formidable flotte du Nord, la moitié sont des sous-marins de chasse à propulsion nucléaire (SNC) équipés de torpilles à tête conventionnelle ou nucléaire. Certains sont même armés de nouveaux missiles de croisière antisurface lançables en plongée.

En plus de cette base aéronavale impressionnante, l'Union soviétique a aussi installé dans sa zone arctique plus de 50% de son arsenal nucléaire aéroporté (bombardiers stratégiques à moyen et long rayon d'action transportant bombes nucléaires et missiles de croisière) qu'elle a réparti dans huit bases aériennes d'importance. Trois de ces bases sont situées à l'ouest, près du théâtre d'opération européen; deux autres sont situées au centre du pays en bordure des mers de Kara et de Laptev; et trois autres sont situées dans la péninsule des Tchouktches, directement en face de l'Alaska, donc tout près du continent nord-américain. L'Union soviétique déploie également au nord du 60e parallèle entre 160 et 200 missiles stratégiques intercontinentaux, soit approximativement 10% de tout son arsenal nucléaire en base terrestre. Le tiers de ces missiles sont pointés vers l'Europe, notamment vers la Scandinavie (missiles SS-18 et SS-19 munis de 6 à 8 ogives de 600 à 1000 KT chacune).

Toute cette formidable puissance militaire soviétique interagit, naturellement, avec celle que lui oppose les pays membres de l'OTAN, en particulier les États-Unis qui recouvrent de leur parapluie nucléaire leurs alliés arctiques et européens. Il faut souligner cependant que si les États-Unis doivent être considérés comme une puissance militaire arctique, ce n'est pas tant en raison du potentiel militaire de l'Alaska qu'en raison plutôt de ses flottes de l'Atlantique et de l'est du Pacifique qui sont appelées à patrouiller les mers arctiques et à y confronter quotidiennement la puissance marine

soviétique. En effet, les États-Unis n'ont installé en Alaska que trois bases aériennes d'importance, soit Elmendorf en banlieue d'Anchorage, Eielson près de Fairbanks et Shemya à l'extrémité ouest de la chaîne Aléoutienne, qui ne logent aucun bombardier stratégique (du moins en temps de paix) mais uniquement des chasseurs-intercepteurs, des avions-radars et des avions de patrouille maritime. Soulignons cependant que les chasseurs-intercepteurs F-15 et F-4E Phantom peuvent être équipés de missiles nucléaires tactiques (1 à 100 KT) qui seraient entreposés, présume-t-on, dans ces mêmes bases aériennes. La US Navy pour sa part ne compte en Alaska qu'une base navale secondaire, sur l'île Adak, au coeur de la chaîne Aléoutienne, qui sert essentiellement de point d'appui aux bâtiments de la III^{e} flotte (est du Pacifique) en mission dans le secteur de la mer de Bering et de la mer de Beaufort. Y est notamment entreposé un stock de grenades sous-marines nucléaires (5 à 10 KT). En comparaison, ce sont des forces relativement modestes que les États-Unis ont installées en permanence dans leur zone arctique. Il faut souligner cependant que la présence nucléaire américaine se trouve renforcée, d'une part, par son aviation stratégique basée sur le continent près du 45^{e} parallèle qui effectue régulièrement des missions d'entraînement jusqu'en Alaska et au Groënland (à Thulé notamment) et, d'autre part, par le déploiement permanent dans les mers arctiques de SNLE, de SNC, de destroyers et de frégates, tous armés de missiles, torpilles et grenades à têtes conventionnelles ou nucléaires, appartenant à la II^{e} et III^{e} flotte de la US Navy.

C'est donc par le jeu du chat et de la souris auquel s'adonnent les puissances militaires arctiques sur les mers, sous les mers et dans les airs que se mesure finalement le degré réel d'interaction circumpolaire liée à la confrontation des forces militaires en présence dans les régions polaires. L'Union soviétique est la plus «arctique» des deux superpuissances. Il fallait donc s'attendre à ce que ce soit elle qui ait le plus activement participé à la nucléarisation de ces régions. Par contre, même si l'aviation stratégique et les II^{e} et III^{e} flottes américaines sont basées plus au sud, il n'en demeure pas moins qu'elles participent directement à la nucléarisation du ciel et des mers arctiques par les exercices et les patrouilles qu'elles y effectuent.

Conclusion

Dès le départ nous nous sommes interrogés quant à l'opportunité de créer une ZEAN dans les régions arctiques. Et pour cause: comme nous venons de le voir, ces régions sont devenues le terrain de jeu des militaires du Sud et leurs jouets sont radioactifs. Arsenaux nucléaires embarqués qui circulent régulièrement dans les mers arctiques; survol de bombardiers stratégiques aux soutes bourrées de mégatonnes; panoplie d'armes nucléaires tactiques stockées dans ces régions pour y être employées en temps de guerre. Nous avons vu également jusqu'à quel point les intérêts stratégiques que possèdent les États-Unis et l'Union soviétique dans les régions arctiques sont en fait liés au déploiement de ces forces de frappe nucléaires. Tout cela nous amène à une conclusion: il est devenu difficile, voire même impossible, dans l'ordre actuel des choses, d'envisager la création d'une ZEAN au sein des régions arctiques. En effet envisager la dénucléarisation de ces régions reviendrait en quelque sorte à faire abstraction de la réalité au sein de laquelle la dissuasion nucléaire est devenue (pour le bonheur des uns et le malheur des autres) l'élément clé du maintien de la sécurité mondiale. D'ailleurs, dans le passé, toutes les propositions de désarmement qui portaient atteinte au concept de dissuasion ont été jugées irrecevables. Le bilan que nous avons dressé plus tôt des ZEAN existantes l'illustre fort bien: seules les propositions qui n'avaient pas pour effet de nier aux superpuissances un territoire jugé vital au déploiement de leur force de frappe ont été finalement retenues. Toutes les autres sont demeurées stériles. Le cas des régions arctiques ne saurait, selon nous, faire exception.

Bien sûr, nous pourrions prévoir des entorses au régime de dénucléarisation afin de minimiser son impact sur la dissuasion nucléaire et de le rendre du même coup plus acceptable aux yeux des puissances concernées. Par exemple, les bases de SNLE et le transit de ces sous-marins pourraient être spécifiquement autorisés au sein de la zone et les batteries existantes de missiles balistiques pourraient être tolérées. Mais cela ne reviendrait finalement qu'à édulcorer le concept de ZEAN et à créer un précédent qui pourrait s'avérer dangereux au moment d'envisager la création d'autres zones ailleurs dans le monde. Il vaudrait mieux, à notre avis, explorer d'autres avenues comme, par exemple, la conclusion d'accords multilatéraux ou bilatéraux de contrôle et de limitation des armes nucléaires soit dans un cadre général ou encore dans un cadre spécifiquement adapté aux régions arctiques.

Quoi qu'il en soit, il nous apparaît clairement que toute éventuelle mesure de désarmement arctique ne saura finalement voir le jour qu'à la suite d'une prise de conscience des intérêts communs et d'un accroissement de la coopération scientifique, économique, culturelle ou autre, au sein du système régional. Cela n'est évidemment possible qu'à la condition qu'il existe chez les acteurs circumpolaires une volonté politique très nette d'agir en ce sens. Or, pour certains, la question n'est pas tant de savoir si cette volonté existe que si elle peut en fait exister. Cette interrogation, lourde de sens et de conséquence, ne trouvera à notre avis de réponse définitive que lorsque les puissances circumpolaires moyennes, comme le Canada, se seront enfin «branchées» en décidant, vis-à-vis de cette prise de conscience des intérêts communs, soit de laisser aux États-Unis et à l'Union soviétique le soin de prendre à cet égard les principales initiatives, soit d'exercer elles-mêmes le leadership qu'elles seraient selon nous non seulement capables mais également justifiées d'assumer.

Références

Arkin, W.M., et Fieldhouse, R.W. 1985. Nuclear Battlefields — Global Links in the Arms Race. Cambridge, Mass.: Ballinger Publishing Company.

Baylis, J., et Segal, G. (éd.) 1981. Soviet Strategy. Londres: Croom Helm.

Bertram, C. (éd.) 1983. America's Security in the 1980's. New York: St. Martin's Press.

Bjol, E. 1983. Nordic Security. Londres: International Institute for Strategic Studies, Adelphi Paper no 181.

Coutau-Bégarie, H. 1983. La puissance maritime soviétique. Paris: Éditions Economica.

Daniels, D.C. 1984. Antisubmarine Warfare in the Nuclear Age. Orbis 3:527-552.

Epstein, W. 1975. Nuclear Free Zones. Scientific American 233:25-35.

Goldschmidt, B. 1980. Le complexe atomique — histoire politique de l'énergie nucléaire. Paris: Fayard.

Gunnarsson, G. 1982. "Icelandic security policy: context and trends". Cooperation and Conflict 4:257-272.

Häggman, B. 1981. "La menace soviétique dans le Nord". Confidentiel 8:7-21.
International Institute for Strategic Studies, 1985. The Military Balance 1985-86. Londres: IISS.
Klenberg, J. 1968. The cap and the straights: problems of Nordic security. Harvard University: Centre for International Affairs.
Lindsey, G.R. 1977. Strategic aspects of the polar regions. Toronto: Canadian Institute of International Affairs.
Newcombe, H. 1981. "A nuclear weapon free zone in the Arctic — A proposal." Bulletin of Peace Proposals 3:251-258.
Ostreng, W. 1977. "The strategic balance and the Arctic Ocean: Soviet options." Cooperation and Conflict 1:41-62.
Purver, R.G. 1981. Arms control in the North. Kingston: Queen's University Press.
Szurek, S. 1984. "Zones exemptes d'armes nucléaires et zones de paix dans le Tiers-Monde." Revue générale de droit international public 114-203.
Williams, J.A. 1984. "The U.S. and Soviet navies: missions and forces." Armed Forces and Society 4:507-528.
Wit, J.S. 1981. "Advances in antisubmarine warfare." Scientific American 2:31-41.

MAMMOTH BONE BREAKAGE PATTERNS FROM LOCALITY 11A, OLD CROW, NORTHERN YUKON TERRITORY

T. Max Friesen
Department of Anthropology, University of Toronto, Toronto, Ontario M5S 1A1

Level: Master's

Abstract

The Old Crow basin, northern Yukon Territory, has produced massive accumulations of Pleistocene vertebrate fossils. Many large mammalian bones, including those of horse, bison, and mammoth, exhibit features which indicate breakage while fresh, before dessication or mineralization occurred. This has been interpreted by several scholars as evidence of human presence in eastern Beringia at a period variously dated from 25,000 B.P. to over 120,000 B.P., constituting proof of an entry by people into the Americas at an earlier time than is accepted by many archaeologists.

The Northern Yukon Research Programme of the University of Toronto retains large collections of fossil material from the region, including a sample collected in 1975 from secondarily deposited point-bar, called locality 11A. All bones encountered in the field were returned to Toronto in that year, thus minimizing human bias in the sample of over 9900 bones.

The study of the 2171 mammoth bone and tooth fragments identified from this sample yielded several new and significant results. Approximately 5% of all bone fragments exhibit fresh breakage but a much higher proportion of longbone fragments, approximately 13%, exhibit fresh breakage. Another important observation is that carnivore gnawing, often cited as a possible cause of Old Crow bone breakage, does not occur on any of the freshly-broken bones; this reduces the likelihood that carnivores were responsible for the breakage.

Key words: Old Crow, northern Yukon Territory, early man in North America, taphonomy, bone technology, mammoth, spiral fracture.

Résumé

Le bassin géologique Old Crow, dans le Yukon septentrional, contient des accumulations importantes de vertébrés fossiles du Pléistocène. De nombreux ossements de grands mammifères: cheval, bison, mammouth, etc., portent les traits caractéristiques d'un bris à l'état frais, avant qu'une dessication ou une minéralisation n'ait pu commencer. Plusieurs chercheurs estiment que c'est une preuve de la présence d'hommes dans la Béringia orientale à une période remontant de −25 000 à −120 000 ans, bien antérieure à l'époque acceptée par de nombreux archéologues.

Le Programme de recherches sur le Yukon septentrional, administré par l'Université de Toronto, a permis de réunir de vastes collections de fossiles de cette région, y compris un échantillon recueilli en 1975 dans un dépôt secondaire de la fouille 11A. Tous les ossements extraits cette année-là ont été retournés pour étude à Toronto, afin d'éliminer toute erreur systématique dans l'identification de plus de 9 900 ossements.

L'étude des 2 171 fragments d'os et de dents de mammouths identifiés dans ce lot a permis d'établir de nouvelles et importantes conclusions. Elle a montré, en particulier, qu'environ 5% de l'ensemble des fragments d'os portent les traits caractéristiques d'un bris à l'état frais, et que 13% environ des os longs offrent la même caractéristique. De plus, on a noté qu'aucune trace de rongement par les carnivores n'apparaît sur les os long brisés à l'état frais. Il est donc controuvé que ces carnivores, comme certains le croyaient, seraient les responsables de ces bris.

Mots-clés: Old Crow, Yukon septentrional, hommes préhistoriques en Amérique du Nord, taphonomie, technologie des os de mammouth, brisure par torsion.

Introduction

Pleistocene fossil bone deposits from the Old Crow Basin have yielded specimens which a number of scientists including Bonnichsen (1979), Irving (1985), and Morlan (1980) have interpreted as being humanly altered. The most numerous category of bone fragment considered to exhibit evidence of human intervention consists of those which are believed to have been fractured while fresh; this form of breakage occurs on a wide range of Pleistocene species including horse, bison and elephant. The interpretation of these bones as artifacts remains controversial among many, perhaps a majority, of archaeologists for several reasons.

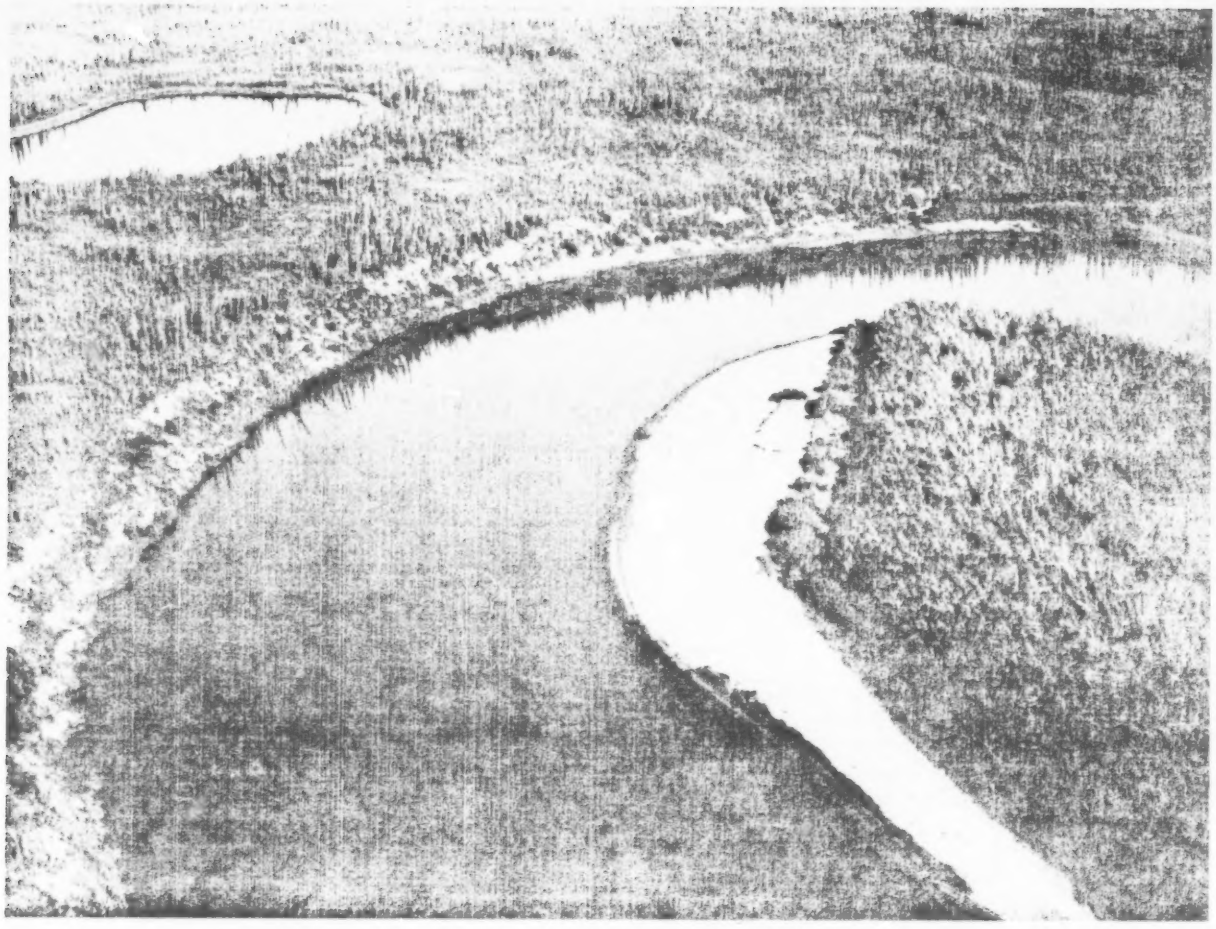


Figure 1. Old Crow Locality 11A, centre, an elongated point-bar of complex origin, has yielded over 21 000 Pleistocene fossils between 1975 and 1979. Photo credit: W.N. Irving

These include the apparent lack of analogous broken bones from other archaeological deposits, the lack of primary stratified sites within the Old Crow Basin, and incomplete understanding of many of the taphonomic factors that have affected the alteration and deposition of bone fragments.

Attempts have been made to establish a technological classification of these fractured bones. (eg. Bonnichsen 1979, Morlan 1980) These studies, while advancing understanding of the various categories of bone breakage, have necessarily been limited by the fact that no large, complete and unbiased sample from a single Old Crow locality has been studied. Most localities have been sampled selectively for palaeontological or archaeological value, rather than completely, because of the difficulty and financial cost of shipping large collections from the Yukon Territory to southern locales. The biases inherent in these samples caused by collecting methods must be an important consideration in any analysis of the Old Crow bone assemblages.

The collections of the Northern Yukon Research Programme at the University of Toronto, hereafter referred to as NYRP, contain the largest samples of Pleistocene bone yet collected from northern Yukon. These collections include one sample from the 1975 surface collections at locality 11A in which approximately 10,000 fossils were collected without bias and shipped to Toronto (Irving and Beebe 1984:68). Although this site had been collected selectively in 1970 and 1972, a factor which surely introduces modern human bias to the sample, 11A–75 materials probably represent the best available opportunity to ascertain the relative frequency of the various types of bone fracture at a large Old Crow locality. This sample and others like it, were originally collected with the intention of providing clarification of bone modification types which could subsequently be compared to excavated assemblages. (Irving and Beebe 1984:74; Morlan 1983:54)

The present study is an analysis of the frequency of various types of fracture which occur on Proboscidean (elephant) bones from 11A–75. Its objectives are to provide a standard against which similar collections can be compared, and to clarify terms and methods used to discriminate between fractures caused by humans and those caused by other agencies.

Locality 11A

Old Crow locality 11A (Fig. 1) is an elongated point-bar deposit of complex origin, one of several such bars located along the Old Crow River which yield vertebrate fossils of Pleistocene age. The matrix of the deposit is coarse sand and fine gravel, which extends from approximately 2m above low river level to more than 1m below low river level, the extent of deepest excavation (Beebe 1980).

Locality 11A is the most prolific Pleistocene bone source yet encountered in the Old Crow Basin, and has produced 21,130 specimens between 1975 and 1979, representing over 62% of the 33,776 bones removed from the Yukon by NYRP during its five-year primary research period (Irving and Beebe 1984:55). Many important individual fossils have been recovered from this locality, including a juvenile human mandible (Irving et al. 1977), several pathological Proboscidean bones (Neill n.d.), and numerous specimens exhibiting fresh fracture and other kinds of alteration.

The bone-bearing deposits represent primarily Rancholabrean fauna, and "may be considered to consist of three components: (1) one older than the Anodonta dates (approximately 10 to 11,000 years B.P.) and consisting of specimens eroded from their primary (or prior) sites of deposition; (2) one contemporaneous with the Anodonta dates; and (3) one deposited in very recent times which includes representatives of (1) and (2)" (Beebe 1980:163). This range of age of the deposited bone, combined with the great range of abrasion apparent on the various specimens, suggests that the 11A point-bar is at least a secondary deposit; and certain portions of the bone assemblage may have been redeposited more than once prior to their final deposition at 11A.

A full discussion of the continuing controversy surrounding the dating of the Old Crow deposits will not be included here. However artifacts have been reported from a range of Late Quaternary strata including deposits interpreted as being of Sangamon age or older (Irving *et al.* 1986; Jopling *et al.* 1981). As I have suggested above, the collections described in the present paper likely represent a range of ages. A series of 24 mammoth bone fragments from the Old Crow Basin, interpreted as artificially modified, was recently dated to between 25,000 and greater than 47,000 radiocarbon years by Nelson *et al.* (1986:750). These bones were collected from contexts similar to Locality 11A, modern river banks and bars, suggesting the probability of a similar age range for the 11A Proboscidean material.

Although locality 11A has been studied by several members of NYRP and other scientists, several important questions remain unresolved. The degree to which the 11A deposits are reworked annually, in particular, is a key question which must be answered before a comprehensive interpretation of its contents is performed. It seems likely that the complex depositional history of specimens found in this locality, which incorporates the results of violent annual spring breakups, involves both exposure of previously buried 11A deposits and deposition of new materials including younger bone and, perhaps, bone of similar or greater age eroding from the banks of the river upstream. The sedimentary context of the OCR 11A collection is described in great detail by Beebe (1980), Irving *et al.* (1977), and Irving and Beebe (1984); palaeontological specimens from this locality have been described by Fitzgerald (1978) and Harington (1977). Readers interested in the history of Old Crow Basin research are referred to Irving and Beebe (1984), Morlan (1980), and Morlan and Cinq-Mars (1982).

The sample

The Proboscidean bones from 11A–75 were chosen as a sample for a study of fracture patterns for several reasons. As is mentioned above, 11A contains the single largest collection of Pleistocene bones from the region, a majority of which have not been previously studied for fracture patterning. It was reasoned, therefore, that this site could provide the largest experimental sample with the greatest range of variation of fracture morphology. The advantage of the great size of the sample combined with the exceptional preservation of the bones, allowing the observation of minute details on the bone surfaces, outweighed the interpretive disadvantage that this sample was not in a primary stratigraphic context.

The 1975 collections were selected for study because of the fact that all bones were collected and returned to the laboratory that year, regardless of perceived palaeontological or archaeological value. This resulted in a less biased sample than has been collected from the locality in other years, when only those specimens perceived to be of archaeological or zoological significance were collected (Irving and Beebe 1984:71), due to the financial and logistical problems of shipping tons of material out of northern Yukon. It was also considered important that the 1975 collections represent the single largest sample of bone in the NYRP collections. Sampling bias in this collection is reduced, but not eliminated, because Irving and Harington had collected approximately 2000 bones from the locality between 1970 and 1974 based on specific archaeological or palaeontological criteria. These biases will be mentioned further as they affect the interpretation of the sample offered below.

Proboscidean bone, was singled out for analysis; because of its size and structure, it is affected in particular ways by taphonomic processes (Irving and Harington 1973; Morlan 1983:259). Because fracture patterns, especially green curvilinear fracture, were specifically being analyzed, I felt that the tendency of elephant bone to be resistant to breakage when exposed to certain taphonomic factors such as carnivore gnawing, might clarify any interpretation of these fracture patterns. Another consideration was the fact that, as all Proboscideans in North America are extinct, one may define a minimum age for these bones (Kurten and Anderson 1980).

Identification of these Proboscideans to species in this sample was not considered to be important. Due to the fragmentary nature of many of the bones, only a small percentage could potentially be assigned to more specific taxa. In any case, we assumed that the bone of virtually all elements of the Proboscidean species known to have inhabited the Old Crow Basin would behave in a similar manner when subjected to loaded force because of their similar size and microstructure. Of those bones which could be identified from the entire 11A sample from various years, amounting to approximately 5000 specimens, over 95% are mammoths, genus *Mammuthus*, while the remainder represent *Mammut americanum* (Kerr), the American mastodont. Most specimens have been identified as *Mammuthus primigenius* (Blumenbach) and *Mammuthus columbi* (Falconer) (Neill n.d.:5).

Research strategy

Research was performed in two main phases, the first of which involved separating the Proboscidean bone from the body of the 11A–75 sample and identifying these bones to one of the following ten element categories:

Crania	Tarsals and Metatarsals
Vertebrae	Phalanges
Ribs	Scapulae
Longbones	Innominates
Carpals and Metacarpals	Miscellaneous

The bones were identified to these element classes rather than to exact element, side, and portion of bone for several reasons. The bone from Old Crow is often fragmentary, not allowing exact identification, despite the excellent preservation of the surfaces of the bone. Other scholars have dealt with the same problem in the past; for example Bonnichsen (1979:91) identified only 4 of 86 spirally-fractured Proboscidean bone fragments in his study of the Old Crow collections; the other 82 were simply classified as "unidentifiable fragments". Given this extremely low incidence of identifiable fragments, general patterns of breakage can be discerned more readily at the level of element classes than at the level of individual elements within those classes. It must be remembered, of course, that different elements can and do fracture in different ways from one another, due both to their internal structure and to their gross external structure.

The second phase of the analysis involved the further division of each element category into categories of bone breakage, taking work by Irving *et al.* (in press) as a point of departure. Four mutually exclusive categories of bone modification were defined before this phase began, the first two of which were further divided into two sections; a brief description of each follows.

(1a) Green curvilinear fracture — multiple

(1b) Green curvilinear fracture — single

Bones are considered to exhibit green curvilinear fracture only if they exhibit the following three characteristics: [1]: a smooth, non-pebbly fracture facet; [2]: a curvilinear (as opposed to straight) plan view; and [3]: an angle between the fracture facet and the exterior cortical surface of less than or greater than but not equal to 90 degrees. These criteria have been defined and refined by several authors as capable of differentiating fractures produced on fresh bone from those produced on dried, dessicated, or mineralized bone (Bonnichsen 1979; Irving and Harington 1973; Morlan 1980, 1983). Single and multiple manifestations of green curvilinear fracture were placed in separate categories to facilitate future analyses of the sample. The term "green curvilinear fracture" has the same meaning as the commonly used term "spiral fracture," however it is applicable to all elements, not exclusively longbones.

(2a) Possible green curvilinear fracture — mineralization

(2b) Possible green curvilinear fracture — abrasion

Many specimens in the 11A sample which exhibit fractures which are curvilinear in outline could not be unequivocably placed in category 1; either because the fracture facet was slightly rough, implying the possibility that the bone on which the facet occurred had been broken some time after mineralization or dessication had begun; or because the bone had been abraded to the point that one could not be sure that the smooth facet had not originally been more rough. It must be remembered that fresh bone has been experimentally demonstrated to break on occasion in such a manner as to leave rough fracture facets; and that many of these category 2 specimens may have been broken while fresh. Despite this fact, however, only those bones which adhered strictly to the above three criteria were admitted into category 1. Specimens placed in category 2 include only those which are very close to being considered green-fractured; in other words those specimens which are heavily abraded or which exhibit very rough fracture facets are not placed in these categories but are, instead, considered to have been broken without green curvilinear fracture (see next category).

(3) Broken without curvilinear fracture

This category contains all bones which exhibit breakage without characteristics considered diagnostic of fresh fracture.

(4) Intact

"Intact," as used here, is a relative term. Those bones which are essentially complete, but which have "nicks" or "grooves" on their surfaces or which have small portions of corners or edges removed are considered, for the sake of this analysis, to be intact.

Auxiliary observations were made on all specimens to define the extent of possible carnivore gnawing on the various bone categories. Carnivore gnawing is a particularly important variable because this process has been proposed as being a likely cause of many of the fractures on the Old Crow bones. Analysis of carnivore-gnawed bones was based on extensive firsthand experience with both natural and artificial bone accumulations exhibiting carnivore gnawing as well as on publications by Haynes (eg. 1983), Brain (1981), and several other authors; therefore confidence is high regarding accurate identification of this feature.

Discussion and interpretations

Results of this analysis are displayed in Table 1. The identification of all Proboscidean bones from the 11A–75 sample to element class has allowed a consideration of the relative proportion of Proboscidea in relation to other taxa in the sample. The breakage study outlined above included only bone. Teeth and tusks fracture in ways very different from bone as a result of both their microstructure and their gross structure; this is characterized by formation in plates or layers. Although a body of methodological knowledge regarding breakage of bone in archaeological contexts is beginning to accumulate (eg. Johnson 1985), the same cannot be said for teeth. They cannot, therefore be considered directly analogous to bone in a study such as this one which deals specifically with fracture types. Teeth and tusks in the collections were counted, however. There were 158 broken and 6 complete teeth, and 680 broken tusk fragments. This total of 844, in addition to the 1327 bone fragments, results in a grand total of 2171 fragments, or 21.8% of the total of 9944 specimens which were collected in 1975.

TABLE 1
Patterns of breakage and carnivore activity on Proboscidean bones from Locality 11A, Old Crow, Yukon Territory.

BREAKAGE CATEGORY	#	% of column	% of row	# carn. gnaw.	Crania		Vertebrae		Ribs		Long-Bones		Carpals/ Metacarpals		Tarsals/ Metatarsals		Phalanges		Scapulae		Innominatas		Misc.		Row Totals	Row % of Sample / Row % of Gnaw
ELEMENT CATEGORY																										
1a Green Curvilinear Fracture - Multiple							1	0.5	2	1.0	47	11.1							1	2.9					51	3.8
							2.0		3.9		92.2								2.0						100.1	0
1b Green Curvilinear Fracture - Single									5	2.6	8	1.9													13	1.0
									38.5		61.5														100.0	0
2a Curvilinear Fracture - Possible Mineralization		7	5.9	5	2.5	30	15.6	45	10.7									4	11.4	1	2.7	10	4.5	102	7.7
		6.9		4.9		29.4	1	44.1	4									3.9		1.0		9.8	2	100.0	7	16.7
2b Curvilinear Fracture - Abrasion		1	0.8	2	1.0	6	3.1	37	8.8											1	2.7	4	1.8	51	3.8
		2.0		3.9		11.8		72.5	1											2.0		7.8		100.0	1	2.4
3 Broken Without Curvilinear Fracture		111	93.3	193	96.0	149	77.6	285	67.5	32	76.2	37	82.2	7	63.6	30	85.7	35	94.6	209	93.7	1088		82.0
		10.2	2	17.7		13.7	4	26.2	20	2.9	2	3.4	1	0.6		2.8	2	3.2	1	19.2	2	99.9	34	81.0
4 Intact										10	23.8	8	17.8	4	36.4									22	1.7
										45.5		36.4		18.2										100.1	0	0
Column Totals		119	100.0	201	100.0	192	99.9	422	100.1	42	100.0	45	100.0	11	100.0	35	100.0	37	100.0	223	100.0	1327		
			2		0		5		25		2		1		0		2		1		4		42*	
Column % of Sample	Column % of Gnaw	9.0	4.8	15.1	0	14.5	11.9	31.8	59.5	3.2	4.8	3.4	2.4	0.8	0	2.6	4.8	2.8	2.4	16.8	9.5			100.0 / 100.0 / 100.1 / 100.1		

*42 Carnivore-gnawed bones = 3.2% of the Sample.

The actual number and percentage of Proboscidean bone fragments of the collections from 11A of that year must be significantly higher than is indicated above due to the fact that many bones are considered unidentifiable to order or smaller taxon; a certain undefinable percentage must be Proboscidea. It should be borne in mind, however, that the over 21.8% Proboscidean bone in the sample is probably significantly inflated due to the ways in which taphonomic factors affect these notably larger specimens. Observation of the complete collections from Old Crow indicates that the Proboscidean bones are, on average, broken into many more fragments per original whole bone than are bones of other species. This is particularly true of teeth and tusks; whereas most teeth of non-Proboscidean species tend to be recovered complete or nearly complete, Proboscidean teeth break into numerous laminar fragments; in some cases there may be hundreds of fragments from a single broken tooth. It is highly unlikely that one fifth or more of all of the individual animals in this region during the later Pleistocene were Proboscidea, although they certainly must have represented a substantial proportion of the animal population. Other taphonomic factors which have not or cannot be controlled for in this study may have influenced the rates of survivorship of the bones of different species in these bone deposits.

The most important results of this study are the frequencies of green curvilinear fracture which we recorded. One will note that 4.8% of all of the bones in the sample display single or multiple green curvilinear fracture, based on conservative determination criteria. A further 11.5% of all of the bones are considered to exhibit "possible" green curvilinear fracture; for a total of 16.3% of the sample representing either definite or possible green curvilinear fracture. The bulk of the sample, 82.0%, is contained in fracture category 3, broken without green curvilinear fracture. Twenty-two intact bones, representing 1.7%, round out the sample.

Green curvilinear fracture affects different element categories to a markedly variable extent. Seven ribs, one vertebra, and one scapula fragment demonstrate green curvilinear fracture; representing 3.6, 0.5 and 2.9% respectively of each element category; while 55 longbone fragments, representing 13.0% of this element category, exhibit the same feature. The remaining element categories, on the other hand, contain no observed fresh breaks. Clearly, the sample is large enough to permit the conclusion that longbones were broken while fresh at significantly higher rates than any other element category. Whether this phenomenon is due to a specific taphonomic factor selectively affecting the longbones or whether the nature of the longbones themselves makes them particularly susceptible to certain kinds of breakage remains to be determined by continuing analysis and experimentation; a combination of the two possibilities is considered likely.

Another question which must be addressed is the relationship between the two above-mentioned variables, element category and breakage category, and the presence of carnivore surficial modification in this sample. Forty-two of the 1296 bones in the sample, representing 3.2%, exhibit evidence of carnivore activity. Such evidence appears to be relatively evenly spread across the different element categories; with the exception of longbones which exhibit 60% of the carnivore gnawed bones, yet represent only 32% of the bone sample. This suggests that longbones were the preferred element class for carnivores present in eastern Beringia during the late Pleistocene.

One important observation made by this study was that not one of the 64 bones definitely broken while fresh exhibits any evidence whatsoever of carnivore gnawing. This will, one expects, lay to rest the contention by several archaeologists including Binford (1981) that carnivores could break larger Proboscidean bones from Old Crow. Many bone fragments in this sample exhibit heavy pitting, gouging and scooping resulting from carnivore activity; yet never do evidence of both carnivore activity and green curvilinear fracture occur on the same bone. One need not argue for or against the theoretical ability of carnivores to break massive Proboscidean bones in order to conclude that carnivores clearly did not play an important role in the breakage observed in the present sample.

Comparison of the breakage frequencies generated by this study with other published studies of Old Crow bones will be limited to Bonnichsen's (1979) study of earlier collections from the same site, Locality 11A; comparisons to other assemblages is continuing. A majority of the bones from Bonnichsen's study of Locality 11A, referred to in Bonnichsen (1979) as Locality 89, were collected in 1970 by W.N. Irving. Bones which were considered to be of possible archaeological significance, including those exhibiting green curvilinear fracture, were selected for return to Toronto where Bonnichsen studied them. His results, therefore, are necessarily biased in favour of green curvilinear, or spiral, fracture. Bonnichsen (1979:89) found that 13.2% (237/1794) of the bones of all medium and large mammalian species had been freshly broken; while 19.5% (86/440) of Proboscidean bones exhibited this modification. Thus, green curvilinear fracture of Proboscidean elements is approximately four times as common in the pre-1975 sample as in the 1975 sample. The two samples exhibit 19.5% and 4.8% frequency of this feature, respectively. This difference is attributable to three factors; the possibility of different applications of fracture recognition criteria by the two analysts involved, the fact that the pre-1975 collections were selectively collected for archaeologically significant specimens, and the fact that the pre-1975 collections may have biased the 1975 collections through exclusion of many of the freshly-fractured bones. It is important to note that those collections analyzed by Bonnichsen (1979) represent the only source of modern human bias in the sample analyzed in the present study. The earlier samples are currently being reanalyzed in order to quantify the differences between them and the 1975 sample; thus allowing definition of sources of bias inherent in the 11A–75 sample.

Summary and conclusions

Bones which exhibit features indicating that they were broken while fresh remain the most numerous, yet the most enigmatic category of evidence from Old Crow cited as indicating the presence of man in eastern Beringia in the Pleistocene. The famous caribou tibia flesher, (Irving and Harington 1973) which initially focussed attention on Old Crow, has recently been redated from approximately 27 000 B.P. to 1350 B.P. (Nelson *et al.* 1986). If this new date is confirmed, this more obvious artifact will be placed chronologically late in the Holocene; thus increasing the emphasis placed on freshly fractured bone in studies of Pleistocene archaeology of the Old Crow Basin. The interpretation of this breakage as cultural remains a controversial one, with authors such as Binford (1981) and Thorson and Guthrie (1984) proposing alternative agents such as carnivore gnawing and river ice, respectively, to explain the fresh breakage. Proponents of the artifactual nature of these bones point not only to the frequency of fresh breakage, but also to the patterned or systematic nature of the breaks themselves (Bonnichsen 1979; Irving 1985; Irving *et al.* in press; Morlan 1980). The clarification and definition of these patterns remains of paramount importance to Old Crow studies.

The present study is largely an observational one, intended to result in a clear statement of the frequency of fresh breakage on a large sample of Proboscidean bone from a single locality in the Old Crow Basin. It is important to note that the frequencies presented here represent an extremely conservative application of previously established criteria for the recognition of green curvilinear fracture; comparisons to other assemblages must consider this fact. Continuing research seeks to develop explicit terminology for use in analyses of similar collections, to compare the results contained in the present study to other published sources, and to attribute the observed breakage frequencies and patterns to one or more specific taphonomic agents. Possible candidates include ice rafting, solifluction, frost heave, trampling, and manipulation by man for tool production and/or marrow extraction.

Acknowledgments

My greatest appreciation goes to W.N. Irving, without whose advice, support, and generosity regarding access to the NYRP collections this work would not have been possible. Chris Neill's help in identification of difficult bones and in the assembly of comparative collections was also a major factor in the completion of this work. Finally, my gratitude for valuable discussion and technical help goes to Ruth Gotthardt, Cameron Hunt, Ingrid Kritsch-Armstrong, and Howard Savage.

This is Contribution No. 64 of the Northern Yukon Research Programme.

References

Beebe, B.F. 1980. A domestic dog (*Canis familiaries* L.) of probable Pleistocene age from Old Crow, Yukon Territory, Canada. Canadian Journal of Archaeology 4:161-168.

Binford, L.R. 1981. Bones: Ancient Men and Modern Myths. New York: Academic Press.

Bonnichsen, R. 1979. Pleistocene bone technology in the Beringian Refugium. National Museum of Man Mercury Series No. 89. Ottawa: Archaeological Survey of Canada.

Brain, C.K. 1981. The Hunters or the Hunted? Chicago: University of Chicago Press.

Fitzgerald, G.R. 1978. Pleistocene grebes from the Old Crow Basin, Yukon Territory. Canadian Journal of Earth Sciences 15(12):1887-1892.

Harington, C.R. 1977. Pleistocene mammals of the Yukon Territory. Ph.D. thesis, University of Alberta, Edmonton, Alberta.

Haynes, G. 1983. A guide for differentiating mammalian carnivore taxa responsible for gnaw damage to herbivore limb bones. Paleobiology 9(2):164-172.

Irving, W.N. 1985. Context and chronology of early man in the Americas. Annual Review of Anthropology 14:529-555.

Irving, W.N. and Beebe, B.F. 1984. Northern Yukon Research Programme: Director's Report 1975-1980. University of Toronto Anthropological Series Report No. 15.

Irving, W.N. and Harington, C.R. 1973. Upper Pleistocene radiocarbon-dated artefacts from the northern Yukon. Science 179:335-340.

Irving, W.N., Jopling, A.V. and Beebe, B.F. 1986. Indications of pre-Sangamon humans near Old Crow, Yukon, Canada. In: Bryan, A.L. ed. New Evidence for the Pleistocene Peopling of the Americas. Center for the Study of Early Man, University of Maine, Orono. 49-63.

Irving, W.N., Jopling, A.V. and Kritsch-Armstrong, I. in press. Studies of paralithic technology and taphonomy, Old Crow Basin, Yukon Territory. In: Proceedings of the First International Conference on Bone Modification, Carson City, Nevada, August 17-19, 1984. Center for the Study of Early Man, University of Maine at Orono.

Irving, W.N., Mayhall, J.T., Melbye, F.J. and Beebe, B.F. 1977. A human mandible in probable association with a Pleistocene faunal assemblage in eastern Beringia: a preliminary report. Canadian Journal of Archaeology 1:81-93.

Johnson, E. 1985. Current developments in bone technology. In: Schiffer, M.B. ed. Advances in Archaeological Method and Theory, Vol. 8. New York: Academic Press. 157-235.

Jopling, A.V., Irving, W.N. and Beebe, B.F. 1981. Stratigraphic, sedimentological and faunal evidence for the occurrence of pre-Sangamonian artefacts in Northern Yukon. Arctic 34(1):3-33.

Kurten, B. and Anderson, E. 1980. Pleistocene Mammals of North America. Columbia University Press: New York.

Morlan, R.E. 1980. Taphonomy and archaeology in the Upper Pleistocene of the northern Yukon Territory: a glimpse of the peopling of the New World. National Museum of Man Mercury Series No. 94. Ottawa: Archaeological Survey of Canada.

Morlan, R.E. 1983. Pre-Clovis occupation north of the ice sheets. In: Shutler, R. ed. Early Man in the New World, Sage Publications: Beverley Hills. 47-64.

Morlan, R.E. and Cinq-Mars, J. 1982. Ancient Beringians: human occupation in the Late Pleistocene of Alaska and the Yukon Territory. In: Hopkins, D.M., Matthews, J.V., Schweger, C.E. and Young, S.B. eds. Paleoecology of Beringia. Academic Press: New York. 353-382.

Neill, C.G. n.d. Proboscidean anomalies and pathologies: bone anomalies and osteopathy in fossil Proboscidea. Northern Yukon Research Programme contribution No. 60.

Nelson, D.E., Morlan, R.E., Vogel, J.S., Southon, J.R. and Harington, C.R. 1986. New dates on northern Yukon artifacts: Holocene not Upper Pleistocene. Science 232:749-751.

Thorson, R.M. and Guthrie, R.D. 1984. River ice as a taphonomic agent: an alternative hypothesis for bone "artifacts." Quaternary Research 22:172-188.

LES FEMMES INUIT ET LE DÉVELOPPEMENT

Hélène Guay

Département d'anthropologie, Université Laval, Ste-Foy, Québec G1K 7P4

Niveau: Maîtrise

Résumé

J'emprunte la lunette théorique du paradigme Femmes et Développement pour situer le rôle joué par les femmes à l'intérieur de la société Inuit contemporaine. Au niveau macro-social Boserup (1970) affirme que la scolarisation est l'outil principal qui permettra aux femmes de profiter du développement. La spécificité de mon étude de cas démontre que la dimension économique (l'autonomie financière) est utile pour l'analyse de la situation des femmes mais qu'elle n'est pas suffisante. Tel que démontré par Bénéria et Sen (1981) le regard doit également se porter au niveau micro-social. Dans la sphère publique, les femmes Inuit profitent du développement. Elles ont un accès non discriminatoire à la scolarisation et plusieurs d'entre elles occupent des emplois de type clérical ou de col blanc sur une base annuelle et à temps complet. Pour leur part, les hommes se retrouvent souvent dans des emplois de col bleu à caractère saisonnier. Une expression de la subordination des femmes Inuit se retrouve à l'intérieur des relations de couple. Mon hypothèse est la suivante: les femmes Inuit scolarisées qui détiennent un emploi rémunéré sont victimes de la violence domestique d'une manière plus fréquente que les femmes Inuit non-scolarisées impliquées dans les activités domestiques. Je définis les limites de l'application du modèle Femmes et Développement en situant la société Inuit à l'intérieur d'un contexte culturel particulier et des rapports de classe à l'intérieur de la société canadienne.

Mots-clés: Femmes inuit, développement, éponymie, socialisation, scolarisation, occupation, violence domestique, Igloolik.

Abstract

I employ for my theoretical approach the paradigm Women and Development in order to define the role played by the Inuit women within contemporary society. From the seventies onwards feminist researchers have been denouncing a trend in development which is unfavourable to women. The analysis is carried out at the macro-social and micro-social levels. The economic dimension (financial autonomy) is useful for the analysis of the situation of women, but it is not sufficient, as is proved by the specific findings of my case studies. Unlike African and Asian women living in peasant societies Inuit women appear to benefit from

development in the public sphere. They have access, free of discrimination, to public education and some of them obtain full-time white-collar jobs which are remunerated on an annual basis; the men on the other hand, frequently fill blue-collar jobs which are seasonal. Boserup (1970) states that public education is the most important means of enabling women to benefit from development. I test his hypothesis using three variables: work in the home, control of fertility and domestic violence. I also look at the circulation of money, in order to determine who controls the available funds in a family. I locate Inuit society within the system of class relations and a particular cultural context.

Key words: Inuit women, development, eponymy, socialization, occupation, domestic violence, Igloolik.

Introduction

Le but de cet article est de présenter ma problématique de thèse c'est-à-dire l'application de la problématique Femmes et Développement (Fs et Dév) à l'étude de la situation des femmes Inuit du hamlet d'Igloolik. Je m'intéresse à la spécificité de l'intégration des femmes Inuit à l'intérieur du processus du développement aux niveaux macro-social et micro-social. Au cours des prochains paragraphes, je présente les grandes lignes du paradigme Fs et Dév; je situe la spécificité de mon étude de cas; et j'introduis les variables qui me servent de limites à l'application d'un modèle d'analyse développé à partir de la situation des femmes paysannes des pays qui composent le Tiers-Monde (TM).

La problématique femmes et développement

Depuis le début des années soixante-dix, l'influence des travaux de recherche émanant de la problématique Fs et Dév s'accroît. Dès 1973, l'amendement Percy adopté aux Etats-Unis stipule la nécessité pour l'aide américaine aux pays en voie de développement de favoriser la participation des femmes au développement économique de leur pays. La proclamation de la décennie de la Femme par les Nations-Unis (1975–1985) a pour objectif l'intégration des femmes en tant que partenaires égales au développement.

Les recherches se sont surtout concentrées dans la sphère de la production. Par exemple, Boserup (1970) a mis en lumière le fait que les femmes africaines et asiatiques sont de plus en plus confinées dans la sphère des activités de subsistance tandis que les hommes sont responsables des cultures d'exportation, donc monnayables. Boserup (1970) attribue cette subordination des femmes, en grande partie, à l'androcentrisme des planificateurs du développement qui introduisent des biais sexistes. Ces planificateurs favorisent nettement les hommes quant à l'accès aux nouvelles technologies et aux cours de formation. Boserup (1970) émet l'hypothèse que le seul moyen pour les femmes de profiter du développement est une accessibilité généralisée à une formation de base.

De récentes publications des auteures telles (Beneria et Sen, 1981; Afonja, 1981; Rogers, 1980; Deere et Leone de Leal, 1981) élargissent le champ d'analyse de la situation des femmes. En effet, une analyse au niveau macro-social permet d'éclairer le fait que les femmes ne sont pas partenaires égales avec les hommes dans le développement. Toutefois, pour vraiment analyser la situation des femmes, il faut projeter un regard critique sur le concept de développement et considérer la place occupée par les femmes au niveau micro-social. Pour (Bénéria et Sen, 1981) la dimension économique, c'est-à-dire l'autonomie financière, est une dimension nécessaire. Toutefois, les domaines de la reproduction et du travail domestique enfin la sphère du privé doivent être pris en compte car ils représentent la véritable zone d'oppression des femmes.

De l'ensemble des questions théoriques qui surgissent de la problématique Fs et Dév je n'en retiens que trois. Les femmes acquièrent-elles une plus grande autonomie personnelle et de l'autorité quand elles profitent de cours de formation et qu'elles s'engagent dans des emplois salariés? Quand la maisonnée ne fonctionne plus comme unité de production, quel en est l'effet sur la division sexuelle du travail? Comment la situation des femmes varie-t-elle en fonction de la classe sociale, du contexte culturel et du type d'emploi? (Patricia et Kelly, 1981:265–267)

Spécificité de l'étude de cas

Quatre élements concourent à particulariser mon étude de cas. Le sujet d'étude femmes Inuit n'a pas retenu l'attention des chercheur-e-s en sciences sociales. Par exemple, Léveillé (1985) documente la cécité presque permanente des chercheur-e-s en anthropologie face aux rôles joués par les femmes au sein de la société Inuit. Ce sont les hommes et leurs activités qui ont retenu l'attention.

La lunette d'approche adoptée pour recueillir les données et les analyser est un modèle élaboré à partir des sociétés paysannes du TM. L'application de la problématique Fs et Dév à l'étude de la réalité des femmes d'une société du Quart Monde (QM) est une initiative originale. Aucun-e chercheur-e n'a jusqu'à ce jour établi un lien entre les femmes Inuit et le concept QM. Il semble que ce soit les dirigeants indiens du Canada qui l'aient utilisé pour la première fois lors du premier congrès des peuples arctiques tenu à Copenhague en 1973. Avec l'aide de Müller-Wille et Pelto (1979:7) j'établis six critères pour définir les peuples autochtones du QM: ils possèdent des droits aborigènes sur le territoire, ils vivent dans des états industriels fondés sur l'expansion du colonialisme, ils forment une minorité ethnique, leurs droits légaux en matière de territoire sont menacés d'extinction, ils participent à un système économique traditionnel et leur autonomie politique et leur développement sont restreints par des gouvernements centraux qui ne leur permettent pas d'agir sur les processus de décision qui les concernent plus particulièrement.

A l'intérieur des sociétés du TM, les chercheur-e-s utilisant la problématique Fs et Dév dénoncent le fait que le développement se poursuit contre les femmes. La singularité de la situation des femmes Inuit est telle qu'elles profitent du développement au niveau macro-social. Les femmes Inuit sont actives dans la sphère de la production. Elles ont un accès non discriminatoire à la scolarisation et plusieurs d'entre elles occupent des emplois salariés de type clérical ou de col blanc.

L'expression de la subordination des femmes Inuit se retrouve dans le non-partage des activités dans la sphère de la reproduction de la force de travail et des tâches domestiques et dans l'inégalité à l'intérieur des relations de couple. Ce dernier contexte retient mon attention. Même si la

violence domestique semble assez répandue, il est très difficile de la mesurer avec précision. La nature privée de la relation qui unit l'agresseur à l'agressée obscurcit la visibilité de la violence conjugale. Ce thème est très peu traité dans la littérature se rapportant à la problématique Fs et Dév. Rogers (1980) décrit pour les sociétés paysannes du TM une hostilité des hommes envers les femmes créée par la domination de ces derniers à l'intérieur de l'économie de marché. Mon hypothèse se fonde sur une situation inversée. Les hommes Inuit contrôlent la famille par la violence parce qu'ils ne peuvent trouver leur place à l'intérieur du développement.

Mon hypothèse centrale est la suivante. Les femmes Inuit scolarisées, qui détiennent des emplois rémunérés, sont victimes de la violence domestique d'une manière plus fréquente que les femmes peu scolarisées, engagées surtout dans des activités domestiques parce qu'elles mettent en question le statut économique comme la position sociale traditionnelle des hommes.

Contexte culturel

Selon les plus récentes données de terrain de l'anthropologue Bernard Saladin d'Anglure (BSD), 15% des personnes membres de la communauté d'Igloolik possèdent une identité générique différente de celle accordée par leur sexe biologique. Dufour (1977) documente l'identification des personnes à un sexe social. Elle affirme que

> La société Inuit confère une identité sociale par dénomination éponymique." (33)

Il faut vivement ébranler l'idée qu'un déterminisme biologique définisse nécessairement la division sexuelle des rôles sociaux. (Idem:78)

A l'intérieur de la société Inuit traditionnelle l'individu reçoit un ou plusieurs noms. Les noms personnels sont asexués et l'usage du patronyme est inconnu. Les noms sont toujours transmis d'une personne (éponyme) à une autre. Généralement, ces noms sont des nécronymes. Il y a création d'une relation homonymique. Le nouveau-né remplace la personne décédée. Comme définition opératoire du concept éponyme, je retiens celle suggérée par BSD:

> "Le fait de donner à un enfant le nom d'une personne adulte vivante ou morte, cette personne devenant l'éponyme de l'enfant." (1970:1013 in Dufour 1977:33)

L'éponyme opère deux transformations au niveau de la classification des sexes: une intervention sur le choix du sexe biologique (Sipinik) et une intervention sur le choix du sexe social (Angutirurtitauvuk: on la fait être un homme et Arnarurtitauvuk: on le fait être une femme). Il est donc évident que la compréhension du phénomène de l'éponymie est fondamentale pour quiconque s'intéresse aux rapports femme-homme. L'enfant sipinik est un garçon pendant sa vie intra-utérine qui décide de devenir une fille au moment de naître. (Dufour, 1977:59) Il y a transformation sociale de garçons en filles et de filles en garçons quand le sexe biologique de l'enfant est contraire au sexe biologique de l'éponyme. (Dufour, 1984:20)

La transformation sociale de garçons en filles et de filles en garçons est visible à quatre niveaux: les vêtements, la coiffure, les tâches et les jeux. Le garçon-social est vêtu et coiffé comme tous les autres garçons de son âge. L'enfant fera l'apprentissage des tâches masculines: chasse, pêche, construction de maisons de neige, etc. L'identification sociale au sexe masculin est complète et durera jusqu'à l'adolescence, c'est-à-dire jusqu'à la veille des menstruations. La fille sociale empruntera la même trajectoire sociale.

De nos jours la transformation sociale du sexe d'un enfant est toujours existante mais s'exprime à un degré moindre. L'adhésion à une religion chrétienne qui enseigne des rites mortuaires différents et l'école arrimée par des personnes ressources de culture différente concourent à diminuer la vitalité de cette pratique. Maintenant, le début de la scolarisation marque le passage de l'identification à un sexe social à l'identification à un sexe biologique.

Rapports de classe

McElroy (1975–1976) étudie l'attitude des femmes et des hommes Inuit à l'intérieur du rapport colonisateurs/colonisé-e-s. D'une part les femmes apparaissent plus coopératives que les hommes au cours des premières décennies de la période de contact. Le développement des relations avec les colonialistes n'attaque pas la pratique des rôles traditionnels féminins. D'une part, les femmes continuent leurs occupations traditionnelles telles que la préparation des peaux et la couture des vêtements. Les hommes habitués à une grande autonomie en termes de temps et d'espace se voient offrir des emplois de manoeuvre à bord des bateaux des explorateurs. Les baleiniers veulent s'approprier la force de travail des hommes Inuit en temps horaire, et les missionnaires ont sérieusement endigué l'autorité masculine des shamans. Il semble donc que les femmes Inuit aient participé au processus d'introduction du capitalisme en milieu nordique d'une manière plus harmonieuse que les hommes.

Pendant la période de transition qui a suivi les premiers contacts avec les euro-canadiens, Matthiasson (1976) et McElroy (1975–1976) s'entendent pour constater que les hommes Inuit se sont impliqués dans l'économie de marché d'une manière plus significative que les femmes. Jusque vers les années 1970, les femmes s'en tiennent aux activités traditionnelles. Toutefois, leurs études démontrent qu'au cours des dernières années, les femmes s'engagent et participent à la vie économique, politique et sociale de leur communauté. Selon l'étude de McElroy (1975) les femmes Inuit préfèrent un style de vie euro-canadien tandis que les hommes Inuit sont ambivalents.

Depuis 1960, au moment de la sédentarisation généralisée des membres de la société Inuit canadienne un système scolaire formel est installé à l'intérieur de chaque communauté. L'école nordique calque son fonctionnement sur celui de l'école sudiste canadienne. Les enfants de sexe féminin et masculin ont un accès non-discriminatoire et généralisé à une formation de base.

Depuis le rapport Hawthorn-Tremblay (1966) concernant l'école en milieu autochtone canadien la situation n'a guère changé. L'école accentue les problèmes identitaires des jeunes autochtones et le taux de décrochage est très élevé. Toutefois, la situation actuelle favorise l'implication des femmes Inuit à l'intérieur du système scolaire. De nos jours, les hommes Inuit ont un type de socialisation qui valorise la pratique des activités traditionnelles telle que la chasse. Des questions de temps et d'espace permettent difficilement le

succès simultané de la pratique des activités cynégétiques et des activités scolaires. Les activités traditionnelles des femmes sont très peu valorisées. Egalement, la pratique des activités traditionnelles qui favorisaient des habitudes de travail de nature routinière facilitent leur participation au système scolaire formel. Je ne possède pas de données quantitatives concernant la scolarisation des femmes Inuit canadiennes. Mais, selon Labrecque (1984), Klein (1980), McElroy (1975, 1976) les femmes autochtones canadiennes sont engagées d'une manière plus constante que les hommes dans les activités scolaires.

L'insertion du mode de production capitaliste à l'intérieur de la société Inuit s'est effectuée presque sans l'intervention de l'Etat. Ce n'est qu'après la Seconde guerre mondiale que les instances gouvernementales canadiennes ont littéralement pris en charge la société Inuit. L'intérêt économique lié aux riches ressources du sous-sol de l'Arctique canadien, la position stratégique du territoire dans le développement des relations américano-soviétiques et un intérêt humanitaire ont motivé l'établissement de nouvelles relations entre les Inuit et le gouvernement canadien. Depuis les années cinquante, l'expansion du capitalisme se fait sentir par une hypertrophie du secteur tertiaire.

Des emplois dans le domaine social sont disponibles. D'après une étude de Labrecque (1984) concernant les femmes Montagnaises de la Réserve de Weymontachie (Haute Mauricie), les femmes entre 20 et 34 ans occupent la presque totalité des emplois rémunérés permanents ou à temps partiel disponibles dans la communauté. Klein (1980) affirme que les femmes Tlingit qui sont plus scolarisées que les hommes occupent les emplois permanents de type clérical ou de col blanc. Pour les deux études de cas mentionnés plus haut, les hommes sont plus susceptibles d'occuper des emplois saisonniers de type col bleu. Enfin plusieurs auteur-e-s (Brody, 1970; McElroy, 1975, 1976; Klein, 1980) font état d'un préjugé favorable de la part des employeurs gouvernementaux ou privés envers les femmes Inuit et leur implication au niveau de l'emploi en général.

L'établissement de relations colonialistes, les changements subséquents dans le mode de production et finalement l'actuel état de grande dépendance économique des Inuit du Nouveau-Québec vis-à-vis le gouvernement central sont des évènements et des situations qui colorent d'une manière permanente les rapports femme-homme. Comme il est mentionné par Etienne et Leacock (1980: 17 in Léveillé, 1985)

> «The effects of colonization on the position of women cannot be dissociated from its effects on the society as a whole. Changes in relations between the sexes can be expected to reflect changes in other social sectors and especially the transformation of productive relations . . . . The necessary transformation of productive relations profoundly affected personal relationships.»

D'après les observations du groupe de travail sur la violence domestique formé par le ministre responsable de la condition féminine (1985) et Lévesque (1985 a, b) la fréquence de la violence domestique est variable d'une communauté à l'autre. Par exemple, au Nouveau-Québec la violence domestique serait beaucoup plus fréquente dans les villages comme Kuujjuak et Kuujjuarapik où la boisson alcoolique est plus disponible que dans d'autres villages de la Péninsule et où la désintégration de l'économie traditionnelle est presque complète. La documentation est peu disponible concernant le sujet d'étude Femmes Inuit et Violence. Toutefois, l'établissement d'une relation entre le changement dans les rôles féminin et masculin à l'intérieur de la société Inuit contemporaine et l'expression de la violence domestique contre les femmes m'apparaît une piste intéressante à explorer. Plusieurs auteur-e-s (McElroy, 1975; Lévesque, 1985; Spousal Assault, 1985) mentionnent le nouveau rôle des femmes à l'intérieur de la société Inuit contemporaine comme condition d'apparition de la violence domestique. Le groupe de travail des Territoires du Nord-Ouest met en relief les facteurs associés à la violence:

> «Changes in traditional family structures, the emergence of the woman as the family provider, increases in unemployment particularly among the men, and the introduction to new values which are in apparent conflict with old values are all put forward as things which influence spousal assault patterns and frequencies.»(11)

Conclusion

L'application de la problématique Fs et Dév dans l'étude du rôle des femmes à l'intérieur de la société Inuit fait apparaître à l'horizon de multiples sentiers de recherche. J'explorerai plus particulièrement l'autonomie financière des femmes Inuit et leur subordination au niveau des relations de couple. L'analyse de la spécificité de l'intégration des femmes Inuit au processus du développement aux niveaux macro et micro-social fournira je l'espère une réponse de plus aux questions théoriques posées par les chercheures intéressées à documenter la place occupée par les femmes à l'intérieur du développement international du capitalisme. L'étude de cas démontrera qu'on ne peut appliquer aux Inuit tels quels les modèles d'analyse du développement élaborés ailleurs pour les sociétés paysannes. Il est également important d'analyser en profondeur certains modèles culturels, par exemple le phénomène de l'éponymie dans le processus de la socialisation dans la société Inuit, afin de mieux contextualiser les rapports femme-homme. Les rapports de classe représentent une autre dimension qui a son importance dans le profil ethnographique des rapports femme-homme. Enfin, l'analyse des rapports femme-homme doit se déployer tant aux niveaux macro-social que micro-social.

Remerciements

Je remercie le centre d'études nordiques (CEN) pour une bourse de voyage qui me permettra de séjourner à Igloolik à l'automne 1986 et à l'hiver 1987. Egalement, le ministère de l'Education du Québec (FCAR) pour une bourse d'étude.

Références

Afonja, Simi 1981. "Changing modes of production and the sexual division of labor among the Yoruba", in Signs, 7, 2, pp. 299-314.

Beneria, Lourdes et Gita Sen 1981. "Accumulation, reproduction, and women's role in economic development: Boserup revisited", in Signs, 7, 2, pp. 279-299.

Boserup, Ester 1983. La femme face au développement économique, Paris, P.U.F.

Briggs, J.L. 1970. Never in Anger, Cambridge, Harvard University Press.

_____ 1974. "Eskimo women makers of man", in C.J. Matthiasson, ed. Many Sisters, New-York, The Free Press.

Brody, Hugh 1975. The People's Land: Eskimos and Whites in the Eastern Arctic, Toronto, Penguin.

Deere, Carmen Diana et Magdalena Leon de Leal 1981. "Peasant production, proletarianization and the sexual division of labor in the Andes", in Signs, 7, 2, 338-361.

Dufour, Rose 1977. Les noms de personnes chez les Inuit d'Iglulik, Université Laval, Thèse de maîtrise, Anthropologie.

_____ 1984. «Les menstruations et la grossesse chez les Iglulingmiut (T.N.O.)», in Recherches Amérindiennes au Québec, 14, 3, pp. 17-25.

Etienne, Mona et Eleanor Leacock 1980. Women and Colonization, New-York, Praeger.

Guédon, Marie-Françoise 1967. Organisations des activités féminines dans la communauté esquimaude d'Ivujivik, Université de Montréal, thèse de maîtrise, anthropologie.

Hawthorn, H.B. et M.A. Tremblay 1966. Etude sur les indiens contemporains du Canada. Besoins et mesures d'ordre économique, politique et éducatif, Direction des affaires indiennes, 2 volumes.

Labrecque Marie-France 1984. «Développement du capitalisme dans la région de Weymontachie (Haute Mauricie) incidences sur la condition des femmes Attikamèques,» in Recherches Amérindiennes au Québec, 14, 3, pp. 75-87.

_____ 1986. Notes de cours, hiver 1986, Séminaire Femmes et Développement, Université Laval.

Klein, Laura 1980. "Contending with colonization: Tlingit men and women in change", in Etienne et Leacock (eds), Women in Colonization Anthropological Perspectives, New-York, Holt, Rinehart et Winston, pp. 88-108.

Léveillé, Danielle 1985. L'androcentrisme en anthropologie, un exemple: les femmes Inuit, Université Laval, thèse de maîtrise, anthropologie.

Lévesque, Georgette 1985 a. Alcohol related wife abuse: The case of . . . an Arctic Quebec community, Université de Montréal, non-publié.

_____ 1985b. La violence conjugale chez les Inuit, Université de Montréal, non-publié.

Mathieu, Nicole-Claude 1971. «Note pour une définition sociologique des catégories de sexe", in Epistémologie sociologique, 11, premier semestre, p. 19.

Mathiasson, John 1976. "Northern Baffin Island women in three cultural period", in Western Canadian Journal of Anthropology, 6, 3, pp. 201-212.

McElroy, Ann 1975. "Canadian Arctic modernization and change in female Inuit role identification" in American Ethnologist, 11, 4, pp. 662-686.

_____ 1976. "Negotiation of sex-role identity in eastern Arctic culture change", in Western Canadian Journal of Anthropology, 6, 3, pp. 184-200.

Mostley, J.C. 1981. Alaskan Native Women's Changing Roles and the Implication for Education, Université de Seattle, Thèse de doctorat en éducation.

Muller-Wille, L. et Pertti J. Pelto 1979. «Stratégies politiques du Quart Monde nordique: Inuit, Cris, Sami», in Etudes Inuit Studies, 3, 2, pp. 5-17.

Patricia, Maria et Fernandez Kelly 1981. "Development and the sexual division of labor: an introduction", in Signs, 7, 2, pp. 268-279.

Rogers, Barbara 1980. The Domestication of Women, London, Tavistock Publications.

Saladin d'Anglure, Bernard 1970. «Nom et parenté chez les esquimaux Tarramiut du Nouveau-Québec (Canada)», in Echanges et communications, mélanges offerts à Claude Lévi-Strauss, réunis par Jean Pouillon et Pierre Maranda, Mouton (ed), p. 1.

_____ 1977. «Mythe de la femme et pouvoir de l'homme chez les inuit de l'Arctique central», in Anthropologie et Société, 3, pp. 79-98.

_____ 1980. «Petit ventre» «L'enfant du cosmos Inuit», in L'Homme, Jan-Mars, 20, 1, pp. 7-46.

_____ 1985. Task Force on Spousal Assault, prepared for the Minister Responsible for the Status of Women, Government of the Northwest Territories.

Testart, Alain 1986. Essai sur les fondements de la division sexuelle du travail chez les chasseurs-cueilleurs, Paris, Editions de l'École des Hautes Etudes en Sciences Sociales.

Tinker, Irène 1979. «Le développement contre les femmes», in Questions féministes, 6, pp. 69-86.

RESERVE DEVELOPMENT AND THE INDIAN ACT: THE CASE OF THE PAS RESERVE, MANITOBA

Judy Head

Department of Native Studies, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0

Level: Bachelor's

Abstract

This paper aims to show that social and economic development on an Indian reserve is possible under the restrictions of the present *Indian Act*. Utilizing The Pas Indian Reserve as a case study, the paper illustrates both the possibilities for development as well as the obstacles that must be overcome in order for a reserve community to pursue development. The study outlines development from the time bands were first given the opportunity to take over the administration of some programs on their reserves until the present date. The legal aspects of development on a reserve are also detailed.

A band which is able to attain some level of successful development under the *Indian Act* should definitely attain an even higher level of success under a system of self-government.

Key words: Economic development, Indian reserves, Indian Act, The Pas Indian Band.

Résumé

L'auteure estime que le développement économique et l'innovation sociale sont possibles dans les réserves indiennes, en dépit des restrictions de la *Loi sur les Indiens* actuelle. Se fondant sur l'exemple de la Réserve indienne de Le Pas, l'étude illustre les possibilités de progrès social et économique, ainsi que les obstacles que la collectivité de la Réserve doit surmonter en cette matière. Elle décrit les progrès réalisés jusqu'à ce jour, depuis que les bandes indiennes ont obtenu la possibilité de prendre en mains l'administration de certains programmes dans leur réserve. Elle envisage également en détail les aspects juridiques des actions de progrès sur les plans économique et social.

La bande indienne capable d'atteindre quelques succès sous l'empire de la *Loi sur les Indiens* devrait en obtenir bien davantage dans un régime d'autonomie.

Mots-clés: Développement économique, réserves indiennes, Loi sur les Indiens, Bande de Le Pas.

Introduction

This paper will demonstrate that even though there have been and still are many obstacles to progress for Indian reserves in Canada, it is possible for development to occur under the present system of authority delegated at the discretion of the Minister of Indian Affairs. A review of the legal aspects of reserve development is detailed and a case study of The Pas Indian Reserve provides an example as to how this can be achieved.

The legal basis for reserve development

In order to understand the process by which Indian reserves may develop it is necessary to examine the legislation by which Indian reserves are presently defined (Sparks, 1985). The *British North America Act*, 1867, Section 91(24) assigns to the Parliament of Canada exclusive legislative jurisdiction for "Indians and Lands reserved for the Indians". Further to this is the *Indian Act* (Government of Canada) which is the federal statute that governs, among other things, land tenure in Indian reserves and surrendered lands (Henderson, 1978). In this Act the "powers" to regulate reserve land are largely retained by Parliament (Henderson, 1978); furthermore, the *Indian Act* (Government of Canada) is the primary instrument through which bands, band councils and the Minister of Indian Affairs manage and administer the affairs of the reserve communities across Canada (Sparks, 1985). Sections 3(1) and 3(2) of the *Indian Act* (Government of Canada) give extensive powers to the Minister of Indian Affairs and his superintendents. As a result of these provisions a Band may be delegated authority and thus "many transactions that would otherwise appear to be forbidden are possible if the Governor-in-Council agrees to declare particular sections of the Act inoperative insofar as they affect a certain band or a certain reserve" (Henderson, 1978).

William H. Henderson in his report *Land Tenure in Indian Reserves* (1978) points out that under Section 60 of the *Indian Act* (Government of Canada) a band can be granted whatever "powers" to manage reserve lands it requests, with the consent of the Governor in Council. The Act confers powers in relation to local government either on the band itself or on the band's council. It defines how a council or band may be constituted in Sections 74 through 80 but it does not specifically provide for the appointment of band staff or set forth the duties for those positions. The Act does not even provide councils with the express authority to employ such staff even though the Department of Indian Affairs and Northern Development (DIAND) provides funding for those positions.

It is generally agreed that sections of the Act pertaining to areas such as land management and the surrender of land are outdated. Some bands, however, are finding the ways and means to develop their reserves in spite of present obstacles.

David G. Sparks in his presentation *Indian Government and Development on Reserve Lands* (1985) discusses Indian government as it is related to development. He outlines four basic requirements for community development: local government that actually governs; stability within the community; provision of services such as water, sewer, fire protection, waste removal, transportation and additional services as needed; and the existence of a positive attitude towards development. He states that this last requirement is of utmost importance and cannot be over-emphasized (Sparks, 1985). In other words it is essential that each community member be supportive of the development of the community as a whole.

Sparks outlines the essential characteristics of local government: a defined territory; a defined population; continuing governmental organization; separate legal identity; autonomy, or a degree of independence; governmental powers; and fiscal independence, or some power to raise and spend money to carry on functions (Sparks, 1985). He says that although Indian bands have all of these they are not put to use. He points to this as an unwillingness to actually govern and says this has hindered the development of reserve lands and communities. Sparks makes this conclusion without reviewing the difficulties faced by those bands who have attempted to implement local government.

Sparks points to the situation where Indian leaders feel they do not have the powers to enact by-laws and he says that it would be difficult to find very many of these by-laws that were ever challenged in court. Again he fails to mention the many by-laws that are passed by band councils only to be rejected by the Minister of Indian Affairs. Sparks feels that the absence of power on the part of a band council is largely a matter of perception. This author also comments on another common complaint made by Indian bands that their by-law making powers are very limited. He feels that lawyers and consultants are to blame for this as a result of their actions in an advisory capacity. Sparks says these people tend to use a municipal format when drafting band by-laws. He points out that municipal governments have a highly structured form of power delegated by the Provincial government while an Indian band government receives its delegated powers under the *Indian Act* (Government of Canada) in a more generalized form. It would appear that this obstacle to local government will continue until a body of court decisions dealing with Indian band by-laws is in existence.

In regard to the subject of taxation powers under Section 83 of the *Indian Act* (Government of Canada), Sparks says:

> Until a significant number of Indian bands with the co-operation of their solicitors draft and enact a sufficient number of taxation by-laws which occupy the field at the local level, and these are challenged in the appropriate courts of jurisdiction, we have no real knowledge as to the extent of a band's power to tax. It is sufficient to say that bands do have power to tax and that power may quite legitimately extend to "lands reserved for Indians" (Sparks, 1985).

The underlying theme of Sparks' paper appears to be that a band will have to take a chance if it wishes to govern extensively on its reserve lands.

The legalities surrounding "surrendered" reserve land also have an impact on the development of Indian reserves. Sections 35 through 41 of the *Indian Act* (Government of Canada) provide for the surrender of reserve lands. Section 37 prohibits the disposition of reserve lands, except as elsewhere provided by the Act, until such lands have been surrendered. Agreement of the electors of a band in the

form of a referendum is required as is the approval of the Governor in Council (Bartlett, 1985). Most developments on reserves require that a surrender of the land take place, although in recent times these have conditions attached to them.

Regarding reserve lands, Richard H. Bartlett has pointed out that the "administrative authority with respect to reserve and surrendered lands is separately provided for in the Act" under sections 18 and 53. There is continuing legal debate on the subject of surrenders and the legal status of the surrendered lands. It will be sufficient here to note that lands on which development is to take place are generally surrendered in order that Indian bands may obtain the funding necessary for the project.

Case study: The Pas, Manitoba

In order to explain the possibilities that presently exist for reserve development, this paper will examine the development of The Pas Indian Band in northern Manitoba. This band illustrates some of the alternatives that exist for development of reserves as well as some of the problems likely to be encountered.

Since the 1960s the Chiefs and Councils of The Pas Band have pursued greater autonomy in the management of Band affairs. This move toward local autonomy was paralleled by a community development strategy aimed at strengthening the Band's economic base and improving the quality of life of its members. In developing a system for local government, the Band pursued three broad avenues of approach — development of administration and program delivery, development of local government authority and development of Band enterprises. The Band presently owns and operates a shopping mall, an I.G.A. grocery store and a trailer court, and administers a large number of residential, commercial and industrial reserve land leases to non-Band members. A community infrastructure has also been put in place to provide services, such as water, sewage and paved roads to the major residential subdivision (Connell and Connell, 1984).

In 1968 when The Pas Band began to administer programs it dealt directly with a District Office of DIAND which was situated in The Town of The Pas. In the 1970's this office was phased out and the Band began to deal directly with the DIAND Regional Office in Winnipeg. This served to facilitate the expediency with which transactions took place. A Tribal Council took over the local co-ordination of programs and acts as a resource center to the seven member bands, including The Pas.

The Pas Band set up a committee and department structure in the early 1970s and in 1984 the administration was organized into nine departments which reported to one of seven Band Committees: Child Care; Public Services; Education; Health and Social Development; Recreation; Finance and Personnel; Planning, Lands and Resource Development. In the 1970s a guide was developed for the Band's community development programs and included an integrated strategy for development of a town center facility, expanded residential areas, development of community safety services and public works facilities, exploration of land use potentials, development of human resources and development of local capabilities to manage community affairs (Connell and Connell, 1984).

The services of a consultant were retained in early 1979 to assess resource potentials on all reserve lands, to develop a land use strategy and to prepare a land use plan to provide a policy framework for land use decisions in the future. The Band then hired its own planner to provide a liaison between the consultants, Chief and Council and Band Administration. The plan provided a co-ordinated set of objectives, principles and policies for nine classes of land use and identified suitable areas for each land use class. This plan was endorsed by Chief and Council in December 1982 (Connell and Connell, 1984).

In 1982 a full-time planner with a graduate degree in natural resources management was hired. This planner acted as a resource person to the Band Development Authority and Band committes, and worked in close affiliation with the Band's Lands Administrator. An expansion and upgrading of water and sewage facilities have recently been completed, and plans for completion of an arena, monitoring of land use applications to ensure compliance with Council policies, development of a housing policy and drafting of land use zoning policy pursuant to Section 81 of the *Indian Act* (Government of Canada) are currently being pursued.

An important element in the development of this reserve is the Lands Department. From 1970 to 1976 the Band employed a Lands Manager who provided a limited form of land leasing management. A Lands Administrator was hired in 1976 and is responsible for land matters encompassed by Section 53 and section 60 of the *Indian Act* (Government of Canada). Land management authorities were granted to the Band Development Authority and the Band under these sections. The Lands Administrator is also responsible for other land matters as they relate to the various corporations which are controlled by the Band. Approximately one hundred leases and permits are administered under the lands program. These leases and permits generate in excess of one hundred thousand dollars in annual rental income.

The function of the lands administration program is to manage all Band lands for the benefit of the Band membership. Areas that must be dealt with in administering the lands program include land exchanges, research, taxation, economic development, jurisdictional disputes, by-laws and many other related problems (Connell and Connell, 1984). An urgent requirement for the lands management program is seen to be a training program for Band members to become skilled in all aspects of land management. The Pas Band is considered to be a forerunner in Canada regarding management of their lands. Within an evolving self-government system, an effective land management program administered by trained individuals is critical for the Band's overall development.

The Band has a complete Land Registry System set up in the Lands Administration office. This system is a duplicate of the one in Ottawa and provides ready access to all documents and survey information which are kept on microfiche. The Band has acquired a computer which stores all the financial land lease data.

There are several problems this department must deal with. One of these is unauthorized interests in reserve land. This may occur when land which is part of the reserve is being utilized by outside parties without permission. Another problem is the Band-owned trailer court which is situated

within the boundaries of The Town of The Pas on unsurrendered land. This poses obvious problems dealing with issues such as jurisdiction of a municipality and development on unsurrendered reserve lands. These and other problems each deal in some way with the legalities of development on reserve lands.

The Band would like to levy a tax on all reserve residents (both Band members and non-Band members) for the purpose of contributing to the costs of the Band-operated school system. There remains some question as to whether or not it is possible to tax the interests of residents who are exercising rights on the reserve under either a lease or permit. Section 83 of the *Indian Act* (Government of Canada) only authorizes the assessment and taxation of interests of persons lawfully in possession of reserve lands.

Jurisdictional disputes with the Town of The Pas are also unresolved. The town is situated on former reserve land which was surrendered for sale in 1906. There are unresolved disputes with respect to certain roads within the town's boundaries which the Band feels are still subject to Indian interest. The delivery of services to Timberland Trailer Court is also a jurisdictional dispute between the two local governments (Connell and Connell, 1984).

As the Band moves ahead to exercise control over its land, problems continually emerge. These problems relate primarily to the administration of Section 53 and Section 60 of the *Indian Act* (Government of Canada).

In order to exercise the authorities delegated to the Band by the Minister of Indian Affairs they have formed a Band Development Authority, congruent to Sections 53, 60 and 83 of the *Indian Act* (Government of Canada). This enables the Chief and Council to exercise local control over management of reserve lands and to make by-laws for raising money through assessment and taxation of interests in reserve land. The Chief and Council have also exercised their powers under Section 81 of the *Indian Act* (Government of Canada) by passing fifteen by-laws with respect to reserve matters such as traffic, dog control, water supplies, waste management, regulation of hawkers and peddlars, public games and amusements, building construction and repair, and the observance of law and order (Connell and Connell, 1984). The Band Development Authority was proposed in 1974 when the Band applied for taxation authority under Section 83. Incorporation of the Band Development Authority as a non-profit corporation as well as approval for Section 83 authority was received in 1976. The Band Development Authority was to be a means by which the Band might derive revenues without incorporating itself or coming under the jurisdiction of Provincial municipal legislation. Obtaining funding for the Band Development Authority proved a difficult task. They did receive limited funding in 1979 and 1980 and were able to draft by-laws and design an administrative system to implement local government. A proposed cost sharing program was submitted to the DIAND in March of 1981. The proposal was to establish the Band Development Authority as the legal and administrative arm of the Chief and Council in all matters respecting local government. At the end of this five year program the Band Development Authority was to be self-sufficient, deriving its revenues through taxation and user fees (Connell and Connell, 1984). However, no funding was received at that time, although the Board of Directors continued to operate without funds or staff.

The Chief and Council see the Band Development Authority as essential to the local government system. The Band presently exercises its by-law and land management authorities to a limited extent. Taxation has not been implemented and full implementation is not considered feasible without funding for the Band Development Authority's pilot program to develop support services.

A summary of the development of the Band's economic enterprises will serve to further outline the possibilities that exist for development.

The economic development of the Band was assisted in 1967 by the construction of the ManFor sawmill/pulpmill complex on land owned by the Town of The Pas. Gravel deposits located on the reserve are abundant and of a high quality and these were used in the construction of the complex. Further to this a gravel operation known as the Nakow Corporation was established in 1976. During the peak years of the 1960s and 1970s revenues were extremely good. Band gravel was also used in the construction of the Otineka Mall, a shopping complex on the reserve, and for other purposes. During the height of the gravel business the Band did not have a policy for managing and allocating gravel revenues. Monies were allocated for purchase of equipment and to offset DIAND program deficits. Consultants' services were also acquired from these revenues (Connell and Connell, 1984).

The Band's first real attempt to establish a business venture was beset by physical and jursidictional problems. This venture was the Timberland Trailer Court which is owned by the Indian Reserve Corporation and was constructed in 1968. Although problems still exist with this business it was a great learning experience for members of the Band.

The major development of the Band seems to be the construction of the Otineka Mall. This mall is owned and operated by the Otineka Development Corporation, Ltd. As early as 1970, the Chief and Council had discussed a small shopping complex. The primary reasons for a shopping center on the reserve were to provide services to Band members and to circulate money on the reserve instead of in the Town of The Pas. It was hoped that a commercial development would also include an arena and a hotel. Studies were conducted and in 1973 the Band incorporated the Otineka Development Corporation for the purpose of developing a shopping center on The Pas Indian Reserve. Construction began in 1973 and the mall was completed by 1975. The cost of the mall at that time was approximately $7.1 million. The mall could not support the payments of a loan that large and therefore the DIAND contributed funds to bring the loan down to $2.5 million by November of 1975. At this time the Otineka Development Corporation took out a debenture with the Bank of Nova Scotia for $2.5 million in loans. The mall was paying the interest portion of this loan and very little towards the principal. In January of 1983, the loan at the Bank of Nova Scotia was at $1.6 million. At this time the Corporation signed an agreement with the Bank to pay $32,000.00 per month and apply the applicable part to interest and the balance to the principal of the debenture.

At the end of September 1985 the balance of this loan was $893,632.94 and it is hoped that the debenture can be paid in full in three or four years (*Natotawin*, 1985).

The controversy surrounding the initial announcement of the building of this mall received great attention. James Burke in his book *Paper Tomahawks* (1976) uses the example to illustrate the point that Canadians express concern about the state of Indian people yet when Indians attempt to do something to develop, these same Canadians complain of unfair competition. In this case the Town of The Pas businessmen failed in their attempt to stop construction of the mall and relations have since improved to some extent.

Other problems encountered by the development were in leasing space to tenants. From the mall's opening date of 1975 through to 1979 the mall became completely leased with 26 retail outlets and 14 different offices (Connell and Connell, 1984). The mall is no longer fully leased and they now face a problem which resulted from the low rental rates originally charged to attract tenants. This has tied the mall up with leases at low returns and is one of the factors in the mall's present cash flow difficulties.

The Otineka Mall serves a shopping area of close to 15,000 people including outlying settlements and reserves within a 50 mile radius. As many as 200 employees have been employed in the stores and offices in the mall. Annual gross sales of $10 million were reached in 1982, representing one-third of the total gross revenue for the Town of The Pas and area. Long term success of the mall, however, depends on a healthy local economy (Connell and Connell, 1984).

Another enterprise, the Neso Corporation, was formed in 1975 and controls the operation of the IGA Foodstore in the Otineka Mall. It was originally incorporated as a joint stock corporation with a partnership between the Band and another individual who was also the manager. This partnership was terminated in 1976 and the Band borrowed money on a federally guaranteed loan for the start-up of the corporation. Revenues from gravel operations were used to acquire the shares of the original partner. The IGA Foodstore is considered by many to be the best in The Pas (Connell and Connell, 1984).

The Pas Band has also made strides in the area of social development. They have developed: a social services department which administers Social Assistance Programs, the Native Alcohol and Drug Abuse Program and Child Welfare Programs; a Health Department; an Education Department; a Public Works Program; a Housing Program; and a senior citizens' home. It is not necessary to go into these in great detail in order to show that this Band has undertaken a great deal of responsibility with regard to its own development.

In summary it is obvious that The Pas Indian Band has taken significant steps over the past 15 years to move toward self-government. It is said that the development of government authorities, administrative departments and program delivery, and Band operated economic enterprises place the Band in a unique position among Indian bands in Canada. The advances that have been made have been made within the confines of the *Indian Act* (Government of Canada) and under the policies of the federal DIAND. Needless to say, the Band's governmental authorities have also been constrained by the *Indian Act* (Government of Canada), federal government policy, and insufficient finances. The Band is now faced with the challenge of overcoming these constraints and moving towards the development and operation of self-governing institutions developed by and for the Band (Connell and Connell, 1984).

An essential ingredient to the progress of the Band was the dedication of certain leaders who were instrumental in the initial start-up period. These people assumed a double role at that time, continuing to serve the people in the traditional way while assuming new political and administrative duties. In order for any Band to progress the commitment of all members and especially the Chief and Council and their administrators is necessary.

A variety of government departments provide services and programs which may be accessed by bands in the process of development. Examples of such programs might be the employment programs which have been provided under the Department of Manpower, health programs under the Medical Services Branch of the Department of National Health and Welfare, make work programs under programs such as the Indian Economic Development Fund or Indian Agricultural Programs. It is imperative that bands be able to co-ordinate these programs and funding sources in such a way that they become beneficial to the overall development of their reserve.

In the area of employment it seems that a change of policy has recently taken place. Make-work projects are no longer being approved. The move is to a more comprehensive approach whereby economic and social development focus on the available human resources. This involves more programs which train individuals for actual jobs available as well as the development of a long-term strategy to co-ordinate training and economic development. This is thought to ensure the participation of those concerned in existing and proposed economic opportunites. Whether this most recent approach will be more effective than past policies remains to be seen.

Conclusion

The extent to which a reserve can progress towards economic self-sufficiency depends on the particular circumstances and location of that reserve. However, The Pas Band has demonstrated in a positive way that progress within the confines of the present system is possible. I believe The Pas case study could serve as a model for development to be adopted by other bands.

References

Bartlett, Richard H. 1985 "Taxation" In: Morse, Bradford W., ed. Aboriginal Peoples and the Law: Indian, Metis, and Inuit Rights In Canada. Ottawa: Carleton University Press. 579-616.

Burke, James. 1976 Paper Tomahawks. Winnipeg: Queenston House Publishing, Inc.

Connell, Glenn, and Connell, Barbara. 1984 Band Government Development: The Pas Band Case Study. A draft report unpublished.

Government of Canada. 1978 Indian Act. R.S., c. 1-6 amended by c.10 (2nd Supp.) 1976-75-76, c. 48. Ottawa, Supply and Services Canada.

Henderson, William H. 1978 Land Tenure in Indian Reserves. Ottawa: Research Branch, Department of Indian Affairs and Northern Development.

Natotawin, The Pas Indian Band newsletter. Vol. 6, Issue 40, November 1, 1985.

Sparks, David G. 1985 Indian Government and Development on Reserve Lands. These materials prepared for Continuing Legal Education, Vancouver, B.C. and presented at the seminar Indians and the Law II.

BUYING CULTURAL PERMANENCE: COPE AND THE FEDERAL GOVERNMENT OF CANADA

Barry A. Hochstein

Department of Political Science, University of Calgary, Calgary, Alberta T2N 1N4

Level: Master's

Abstract

In 1984 the Committee for Original Peoples' Entitlement (COPE) reached an agreement with the federal government of Canada regarding a land claim. The Western Arctic Land Claim: COPE Final Agreement provided land, mineral rights, cash and interest-free loans to the Inuvialuit (Inuit of the Western Arctic). Additional provisions, similar in wording and intent to the signed "numbered" treaties in Canada, extinguished the aboriginal rights of the Inuvialuit and permit the expropriation of Inuvialuit land with, or in certain circumstances, without federal cabinet approval. These latter two provisions appear to be in direct opposition to the 1981 Canadian Constitution which entrenches aboriginal rights in Sections 25 and 35. This dilemma reflects the continuing ambiguity in Canadian politics and the judicial system of what actually constitutes "aboriginal rights".

Research conducted within the Inuvialuit Settlement Region indicates that the Inuvialuit do not feel any aboriginal rights have been extinguished. Rather, all the claims of land, self-government and cultural continuity are felt by COPE to be included in the Western Arctic Claim. Extinguishment, to COPE, means there will be no further land claims by the Inuvialuit. It extinguishes no other rights.

Canada has continued a policy of recognition of aboriginal rights to extinguish such rights for development, such as occurred on the prairies. This policy does not appear to have changed, particularly in view of hydrocarbon development in the Canadian Beaufort Sea.

The conciliation of these two seemingly opposite stances makes it extremely likely there will be political negotiation as guaranteed in the first amendment to the Canadian Constitution, or even litigation, occurring as a result of the discrepancies in what actually constitute the whole of "aboriginal rights". Land "rights", or claims, no longer appear to form the substance of "aboriginal rights".

Key words: Canada, aboriginal rights, COPE, extinguishment, land claims.

Résumé

En 1984, le Comité pour la reconnaissance des droits des Autochtones (COPE) avait conclu un accord avec le gouvernement fédéral du Canada à propos d'une revendication territoriale. Cet Accord, le «Western Arctic Land Claim: COPE Final Agreement» prévoyait des cessions de terres, droits miniers, argent et prêts sans intérêt aux Inuvialuits (Inuit occidentaux). D'autres stipulations, d'énoncés et d'objectifs similaires à ceux des traités signés et «numérotés» du Canada, abolissaient les droits des Inuvialuits en tant qu'Autochtones et permettaient l'expropriation des terres inuvialuites sous réserve de l'approbation du Cabinet ou, dans certains cas, sans celle-ci. Ces deux stipulations paraissent directement contraires à la Constitution canadienne de 1981, dont les articles 25 et 35 garantissent les droits des Autochtones. Cette incompatibilité met en relief l'ambiguïté constante de la politique canadienne et du pouvoir judiciaire en matière de ce que sont en fait les «droits des Autochtones».

L'enquête menée dans la Région des terres inuvialuites montre que les Inuvialuits estiment qu'aucun de leurs droits en tant qu'Autochtones n'a été aboli. Le COPE estime plutôt que les revendications de terres, d'autonomie et de pérennité culturelle sont inscrites dans le Western Arctic Claim. L'abolition des droits, selon le COPE, signifie simplement que les Inuvialuits ne présenteront plus de revendications territoriales supplémentaires. Aucun autre droit n'aurait été aboli.

Le Canada a poursuivi sa politique de reconnaissance des droits des Autochtones afin de couper court à la présentation d'autres revendications, comme cela s'est produit dans les Prairies de l'Ouest canadien. Il ne semble pas que cette politique ait changé, en particulier à propos des découvertes pétrolières dans la mer de Beaufort.

L'effort de conciliation de ces deux positions apparemment opposées rend extrêmement probable une négociation politique, telle qu'elle est garantie par le premier amendement à la Constitution du Canada, et même des procès, qui résulteraient des antinomies dans ce qui constitue actuellement les droits des Autochtones. Les «droits territoriaux» des revendications ne paraissent plus constituer la substance des «droits des Autochtones».

Mots-clés: Canada, droits des Autochtones, COPE, abolition, revendications territoriales.

Introduction

In 1984 the Committee for Original Peoples' Entitlement (COPE) settled a land claim with the government of Canada. COPE, representing the Inuvialuit, or Inuit of the Western Arctic, agreed to accept designated lands and rights in return for extinguishing all further rights and claims against the government of Canada. The settlement also included substantial capital advances to the Inuvialuit, some in direct cash transfers, some as interest free loans and additional provisions regarding royalties from non-renewable natural resources extracted in the Inuvialuit Settlement Region.

This paper addresses the fact that the Inuvialuit extinguished all their aboriginal rights "whatever they may be"[1] as part of the contractual obligations to achieve settlement. There are two significant points related to this extinguishment of rights.

First, the Canadian Constitution Act (1982) entrenches "existing aboriginal rights" in Part II, Section 35.[2] A question arises — How can the government of Canada extinguish rights which, although undefined, are entrenched in the Canadian Constitution? This begs the question of what are the rights referred to in both the Western Arctic Claim: Inuvialuit Final Agreement and the Canadian Constitution Act, 1982. Peter Hogg notes that

> Section 35, by itself, consists of Part II of the Constitution Act, 1982. It is outside Part I, which is the Canadian Charter of Rights and Freedoms. This carries the advantage that the rights referred to in s.35 are not qualified by s.1 ("such reasonable limits prescribed by law as can be demonstrably justified in a free and democratic society"). However, it carries the disadvantage that the rights are not enforceable under s.24 (which permits enforcement only of the Charter).[3]

The second point is that the Inuvialuit do not admit that they have extinguished any rights in the Western Arctic Claim.[4] In an interview with Inuvialuit leaders, the response to the question of extinguishment was met by surprise that anyone could claim that their rights had been extinguished; they believe they have had their traditional rights affirmed and guaranteed in legislation, backed by the Constitution's guarantee of "existing aboriginal rights". The Inuvialuit recognize that the only rights extinguished were those that they did not have.

Some explanation is required for this latter belief. The Inuvialuit feel that the rights which should have been recognized in the past are recognized in the Western Arctic Claim. The Inuvialuit refer to the idea that their rights have been "affirmed", rather than "granted". Because the Inuvialuit feel all the rights which they should have are detailed in the Western Arctic Claim, they do not feel that the extinguishment clause has any effect upon them. It, in their terms, extinguishes only that which they do not have.

This notion reflects the government of Canada's inclusion of the term "existing" in Section 35 of the Constitution, defining aboriginal rights. Extinguishment limits the definition of aboriginal rights. By specifically delineating aboriginal rights in the settlement, the Inuvialuit dealt with specific rights, rather than dealing in terms of the vague definition "existing aboriginal rights". The Inuvialuit have, in a sense, preceded the actions of most Canadian native people, by defining their rights within the context of the Western Arctic Claim, while other groups are attempting to reach a national consensus, or at the very least, reach regional consensus.

This gives the Western Arctic Claim a case for special attention by native peoples in Canada, and possibly in international circumstances where native rights are as yet undefined or subject to litigation. The Western Arctic Claim stands as a precedent for future claims in Canada in two respects. First, it is the first land claim settlement for native people since the inception of the Canadian Charter of Rights and Freedoms in the Canadian Constitution in 1982. Second, it is the first land claim settlement in the north, reflecting a special case of unsettled claims with a people who have had very few historical dealings with the federal government and are under no treaty.

Aboriginal rights

The history of Canadian, and earlier British policies of dealing with indigenous peoples reveals the underpinnings of current native land claim settlements. The recognition of "aboriginal rights" has been evident in North America from the earliest discoveries. British discoverers were particularly active in this recognition. The British recognized that the original inhabitants had some form of claim to the land traditionally occupied. This recognition came formally in the Proclamation of 1763, in which the Crown formally stated the position of the British government towards the original people of Canada. It is noteworthy that this same proclamation has been included as a reference in the Canadian Constitution.[5]

The British would then seek to remove aboriginal title to the land by a contractual arrangement with the indigenous peoples, or title-holders. There has been a consistent ambiguity in native-government relations due to the British definition of land and title to the land.

Native people, or original people of Canada have never held a similar notion of "title" to the land, but believed that the land belonged to all people, held in common for their use. This notion has close ties to the religious beliefs of the native people, and thus adds a "sacred" aspect to any connotations about the land. The British concept of land is a much more "selfish" or individualistic approach to land, which, in a sense was almost sacrilegious to the native people. This contradiction in terms and concepts has led to a continual state of opposition between native peoples and the government of Canada.

What has occurred, in essence, is the conflict between two cultures, each with a concept of land and title, neither of which has been mutually compatible with the other. This may explain why the first and earliest theories of aboriginal rights dealt almost exclusively with the land. Land provided something tangible to each side of the negotiations in treaty making and land claims. Unfortunately, the abstract concepts each held were not transferred to the other party. The federal government obtained legal title and extinguished future claims with their "legal" document. The native people obtained a specific parcel of land and some compensation, not fully understanding the concept of a limited land area of so many "acres". They did understand sharing the land, not fully recognizing the impact of their tacit agreement.

What native people saw were a few white people wishing to work the land and trap in outlying regions. They had no knowledge, at least at first, of the impending immigration being set up by the federal government. The north has been spared this immigration, at least on a permanent basis. The "boom and bust" economic cycle of the north resulted from the economic surges of natural resource values and the harsh, cold and un-arable land, which could not support a large population for any length of time.

Changes in the theory of aboriginal rights

Since the inclusion of aboriginal rights in the Canadian Constitution, there has been a move to affirm native political rights. This is an entirely new concept for the government to accept. This concept has been one recognized and continually affirmed by native peoples, but one that has

been denied to them, except within the context of the Indian Act. The only political action available to native people in southern Canada has been within the context of the band. More recently, following the 1969 White Paper, regional organizations appeared to voice concerns of provincial and national lobby groups, but the very lines of organization were flawed from the outset.

One example of such a flaw is the Cree Indians in Alberta. They belong to a provincial brotherhood, which is composed of other tribes and bands, some of whom were traditional enemies. There is still a sense of "hostility" prevalent among the elder natives, which does carry over to the youth. The regional flaw is two-fold. First, "Indians" are lumped together in a regional voice which does not accurately reflect the values of any single group within the region. The social and cultural characteristics of each band are unique. The Indian people of southern Canada are not a homogeneous group.

The second regional flaw is that the boundaries of the Indian people do not reflect traditional boundaries. Using the Cree again as an example, one tribe has been divided by the Alberta/Saskatchewan border, with each portion of the tribe belonging to its respective provincial Indian Brotherhood. The problem is exacerbated at the international level where, for example, Indian tribes and nations along the Alberta/Montana border have been split by the creating of an arbitrary international boundary. The geographical boundaries of the original people of Canada, until the two most recent land claims, have not been taken into consideration, except perhaps where reserves were created in a small part of traditionally occupied areas.

In the north, the native peoples have been much more fortunate, in at least one sense, than the native people of southern Canada. There have not been treaties ratified (I refer to "ratified" treaties, specifically regarding the status of Treaty 11, which has not been proven to be a legitimate contractual arrangement) which could provide any impediment to the settlement of land claims, based on traditional occupation in northern areas.

In fact, Canada has actually used the occupation of the north by original peoples as one factor in claiming the Arctic Islands as sovereign Canadian territory. One example has been the settlement of Grise Fiord, Northwest Territories, which was created by the federal government in the 1950's for the express purpose of maintaining sovereignty in the Arctic.[6]

The Inuvialuit have been the first Inuit to settle a comprehensive land claim, with additional Inuit claims currently under negotiation. That the Inuvialuit have reached a settlement after the patriation of the Canadian Constitution is also noteworthy. To understand how the Inuvialuit were able to reach this goal, despite criticism of "selling out" and the fact that they did include a clause allowing the federal government to extinguish their aboriginal rights "whatever they may be", involves understanding what the federal government perceives in the settlement issue, and what native people perceive in the same circumstances.

Federal policy, aboriginal rights and extinguishment

The federal government maintained for over a century that the native people of Canada did not have aboriginal rights. What they were perceived as having was aboriginal "title" to traditionally occupied lands. The government could, through its power as the sovereign, extinguish these rights unilaterally, without consultation with the parties affected. This occurred most notably in British Columbia with the Nishga Indians. The result of the Calder case,[7] as is well known, was to provide a split decision on the recognition of aboriginal rights, which was later perceived by policy makers in the affirmative — that is, that native Canadian peoples had rights which were tied to their former and current occupation of the land. Unfortunately, for the plaintiffs (the Nishga Indians), the court also recognized that such aboriginal title could be extinguished by any act of legislation which would in effect nullify such rights.

Thus, the landmark Calder case provided aboriginal people with the notion, in the perception of federal policy-makers, that native people did in fact, as well as in law, have "aboriginal rights". For the first time in native people/federal government relations, there was a recognition that aboriginal rights existed.

For the next decade, aboriginal rights equalled the notion of land rights.[8] Claims were pursued on this basis, and one claim, the James Bay Agreement, was completed. When the Liberal party regained a majority government in 1980, Prime Minister Pierre Trudeau embarked on the goal of patriating the Canadian Constitution and creating, for the first time in Canadian history, a constitutional Charter of Rights.

Native Canadian peoples responded with an overwhelming reaction to keep the original agreement with Great Britain pertaining to native peoples in the hands of the British Government. When their direct appeals to the Queen and the House of Lords were not accepted, they concentrated their efforts in keeping their rights, as they believed they had, entrenched in the Canadian Charter of Rights and Freedoms and Part II of the Constitution Act, 1982.

Their major opponents were the provinces, who saw a possibility of undefined, cumulating rights for native peoples. The end result was a compromise which saw aboriginal rights entrenched in the Constitution, but limited by the additional word "existing". This then opened a new door to lawyers, judges, policy-makers and native people as to what constituted "existing" aboriginal rights. Prior to the Calder case, there were no recognized aboriginal rights, except for the treaties signed between sovereign powers and the native people of Canada, mostly the Indians of southern Canada.

In terms of power and legitimacy, native rights can be viewed as existing in different levels corresponding to the power and legitimacy of the laws which govern Canadian political activities. Until 1973, the federal government of Canada considered native people only insofar as was needed under Section 91(24) of the British North America Act (1867). The rights guaranteed in the BNA Act were the right to deal exclusively with the federal government, versus the provincial legislative assemblies. This initial act by Parliament moved native affairs, regarding Indian and Inuit people, above the level of provincial politics.

The Calder case moved the concept of rights up another level to the recognition of aboriginal title, based on a usufructuary right. Jean Chretien, Minister of DIAND in 1973, specifically recognized this in the policy statement whereby claims based on aboriginal title would be entertained by the government of Canada.[9] What followed was a considerable amount of negotiation between native people and federal departments, where native people would express all of their concerns, or rights, which were based in a unique cultural notion of being "tied to the land". From the federal viewpoint, the issue was land, and who had title to the land. If a case could be reasonably substantiated that native people "owned" land, based on the principle of the usufructuary right, a claim could be settled.

The inclusion of aboriginal rights in the Constitution moved these rights up another level, with the provision for continued conferences at the First Ministers' level, regarding aboriginal rights. Federal reports since that time have recommended Indian self-government and various ways of implementation of such a new political entity.[10]

What appears to be the final level for aboriginal rights to reach is the constitutional entrenchment of what native people view their rights to be, not just what federal parliamentarians express them to be.

What has evolved, in a rather short time, has been the recognition that native Canadian peoples, defined in the Constitution as Inuit, Indians and Metis, have at least two different aboriginal rights: first, they have the right to the land they have traditionally occupied, unless such rights were extinguished by some act of legislation; second, they have political rights, which are as yet undefined, but real.

The current status of aboriginal rights is, then, the splitting of these two rights — land rights and political rights. It should be noted, however, that this is policy formulation, not law. For there to be firmly entrenched aboriginal political rights will require either some form of legislation asserting such, or a constitutional amendment affirming such rights.

As of 1986, the federal government recognizes only that aboriginal rights are equal to land rights.[11] This legal basis for negotiations is in the process of change, and given the recent movements in the development of aboriginal rights, will likely be altered with the inclusion of native self-government rights, either in the form of legislation or entrenchment in the Constitution.

The current federal policy is to negotiate with aboriginal peoples regarding their claims. At the current time, pending any changes in the definition of "aboriginal rights", the only claims that will be accepted will be those based on the concept of aboriginal title. In discussions with the current negotiators of comprehensive claims, they have indicated that any inclusions of rights other than those relating to the land will have to be exempted, or included with a disclaimer pending new changes to recognize aboriginal political rights.[12]

COPE and the rights of the Inuvialuit

The Committee for Original Peoples' Entitlement was formed in 1970. It developed over the 1970's as a voice for all native northern peoples to have their concerns heard. Although the timing of the origin of COPE falls neatly after the 1969 White Paper, interviews with northerners revealed that there was no concern over aboriginal rights, as southern Indians had, because they were not affected by the Indian Act, and had never negotiated with the government regarding aboriginal rights.[13]

The initial efforts of COPE were primarily directed against oil and gas exploration in the N.W.T., where the Inuvialuit maintained a current traditional native economy. The threat existed that the traditional native economy, basically hunting, trapping, fishing, sealing, whaling, gathering and other subsistence occupations could be disrupted by oil exploration companies. The Inuvialuit documented several claims of trappers who had animal life killed in construction areas, fresh water streams cut off from native users, and in trapping areas, cases of environmental damage that would disrupt their traditional food and fur supply.[14]

In 1973, COPE lost much of its initial membership through attrition to new, regionally and racially-based interest groups. The Dene to the south had formed and encouraged the Dene people to belong to the Indian Brotherhood of the N.W.T., while in the central and eastern Arctic, the Inuit formed the Inuit Tapirisat of Canada, which called for membership from all Inuit, including the Inuvialuit. COPE maintained its Inuvialuit membership from 1973, and settled on membership from only six communities, representing most of the native people which had social, cultural, family, economic, religious and other ties with each other. These six settlements were Aklavik, Inuvik, Tuktoyaktuk, Holman, Sachs Harbour and Paulatuk.

With a definite membership agreed upon, the Inuvialuit began focussing their activities on reaching a land claim. This was enhanced by the decision of the Calder case in 1973, in which the Inuvialuit were included for a period of time as interested parties. The recognition of aboriginal rights and the 1973 federal policy statement provided the impetus for COPE to seriously begin negotiations. Earlier advice from northern consultants had prepared COPE with land use occupancy studies, papers on traditional use of the sea ice, and clearly defined concerns of the Inuvialuit and remedies, based on the continuing observations of the Alaska Native Claims Land Settlement, which could hopefully address the concerns of the Inuvialuit.

While negotiations continued between COPE and the federal government, oil and gas exploration in the Inuvialuit region — the Beaufort Sea-Mackenzie Delta, increased at exponential rates. The additional impetus of national fuel self-sufficiency was created in 1973 by the OPEC oil crisis. Frontier hydrocarbon exploration took precedence in the minds of the policy-makers over environmental concerns.

This is where the real issues of differences between northerners and federal policy makers can be clarified. As suggested by Roger Gibbins, the north simply does not count. In terms of federal-territorial relations, the federal government holds the upper hand at all times in the para-colonial political relationship. What matters in terms of federal northern policy is what concerns Ottawa — not the Northwest Territories.[15]

It should be noted, however, that when territorial and federal goals overlap, the north benefits. Such examples exist as the Berger Inquiry into the Mackenzie Valley Pipeline, the increase of health benefits in the Northwest Territories, and the increasing devolution of power to the Territorial government. However, when the goals conflict, Ottawa will always win. To consider the effectiveness of the north as a political power, one only need look at either Quebec or Alberta in federal-provincial power struggles. In the case of Quebec, there was no support for patriation of the Canadian Constitution and creation of the federal Charter of Rights and Freedoms, as the continuing lack of a signature by Quebec attests. In the case of Alberta, the power struggle based on "rules" between Prime Minister Trudeau and Premier Peter Lougheed was circumvented by the federal government changing the rules (which it has full authority to do) which, in essence, became the National Energy Program (1980).

The evidence is that Quebec with its extremely large population, and Alberta with all its oil and gas resources could not win against federal determination (and the power of Parliament). The north, with a population rivalling that of a small city, has no chance of winning against federal policy intentions. It can only influence that policy as much as possible, and create as much public support in the south for its goals as it can.

In 1973, COPE asked for a minimum three year moratorium on offshore drilling in the Canadian Beaufort Sea.[16] Basically, this moratorium was hardly considered. The Dome Petroleum drillfleet, Canadian Marine Drilling, was already in preparation. The following year's supplies were sent up to precede the drilling season which commenced in the summer of 1976.

Undaunted, COPE kept at the negotiations, which produced an Agreement-In-Principle in 1978. Unfortunately, 1979 saw a new Conservative government take power and shelve the land claim. 1980 saw the sudden defeat of the Conservative government and the attention of native people, including the Inuvialuit, focussed on saving and affirming aboriginal rights in Prime Minister Trudeau's ambitions to patriate the constitution and create an entrenched Charter of Rights and Freedoms.

As if to show continued goodwill towards the native people of Canada, Trudeau found the opportunity to see an agreement reached with the Inuvialuit just before he retired as the political leader of Canada. The Inuvialuit Final Agreement was reached just weeks after Trudeau's announcement of resignation in 1984. The announcement justifiably concerned the Inuvialuit, who had been "shelved" once before with a change of government. With another possible change in the immediate future, an agreement was reached, but through all the negotiations, there was a reasonable consensus on the terms made by the Inuvialuit.

In none of the negotiating documents did the question of extinguishment arise. It was circumvented by the Inuvialuit, who attempted to have all of their rights contained within the Final Agreement. It was expected by the federal government, as the price to pay for settling once and for all, including a substantial cash settlement for compensation and amelioration of northern problems for native people.

My conclusions are that the federal government expects native rights to be extinguished in a land claim — a condition which has prevailed since the first treaties. What the federal government has extinguished, however, has been the vague aboriginal title to the land — being traded for a delineated, politically-understood region and rights associated with ownership and control over that region. The extinguishment clause in all of the federal documents to date must recognize that aboriginal title is not the full extent of aboriginal rights. Political rights of native people, as recommended by federal task forces on this issue, should be affirmed and entrenched in the constitution. These political rights must be defined as explicitly as the notion of aboriginal title has been.

The example has been set by the Inuvialuit in the Western Arctic Claim. An agreement was made which saw extensive and very real negotiations between northern original peoples and the federal government of Canada. The Inuvialuit believe they have had all of their rights as aboriginal people affirmed in the Inuvialuit Final Agreement; these included notions of self-government, cultural continuity and control of game management consistent with traditional native economies.

This is not to suggest that the Inuvialuit Final Agreement has provided the "perfect" example of a land claim settlement. There are some problems which have been identified for future clarification, particularly regarding the legal wording of the claim.[17] This does not mean, however, that the COPE agreement should be overlooked as a precedent to future comprehensive land claims. The principles followed by both parties have merit in producing an agreement. Considering the timing of the settlement, following the patriation of the Canadian Constitution, the COPE settlement should be worth a detailed examination regarding aboriginal rights. COPE believe that they have their rights guaranteed in the Final Agreement. The federal government believes they have settled the claim for all time. If both are correct, the obvious problem of extinguishment stands out clearly as an anomaly.

The rights claimed as affirmed by COPE are not as clear in practice as in writing. Options for self-government and constitutional guarantees are very ambiguous. If the perceived movements towards native self-government proceed in the current direction of succeeding in that ambition, the "rights" of the Inuvialuit will then be affirmed; if the ambitions towards native self-government are in some way thwarted, whether by federal or territorial politics, COPE's intentions of cultural permanence may be threatened.

The concept that native people in Canada have extinguished aboriginal rights "whatever they may be" is not in question. This clause in every treaty and land claim must be reviewed as the notion of political rights, now part of the Canadian Constitution and yet undefined, takes form and substance. Native people in Canada have political rights different in form from other Canadians, but nonetheless as important for their continued cultural uniqueness which adds to Canadian life. European and other immigrant citizens who have created and adapted to the Canadian political system should in some way be equally capable of adapting to its original inhabitants, particularly the original northern peoples who provide Canada with such a colorful identity.

References

1 DINA, The Western Arctic Claim: Inuvialuit Final Agreement, Ottawa: DIAND, 1984, p. 3, Sec. 3(4).
2 Hogg, Peter W., Canada Act Annotated, Toronto: Carwells, 1981, p. 81-82.
3 Peter Hogg, ibid, p. 82.
4 Interview with Nellie Cournoyea, Inuvialuit Regional Corporation, June, 1986. The same information was related by Agnes Semmler, past President of COPE.
5 For a detailed exposition of the history of early policies see Peter A. Cumming and Neil H. Mickenberg, Native Rights In Canada, Toronto: The Indian-Eskimo Association of Canada in association with General Publishing Co. Ltd., 2nd Edition, 1972 and Government of Canada, Indian and Northern Affairs, The Historical Development of the Indian Act, Ottawa: DIAND, 2nd Edition, 1978, and Handbook of Case Law On The Indian Act, Ottawa: DIAND, March 1984.
6 Outcrop, NWT Data Book 84/85, Yellowknife: Outcrop, 1984, p. 158.
7 i.e. Calder et al v. Attorney-General of B.C., 1973 SCR 313.
8 The authority for this theory continues to be Cumming and Mickenberg, Native Rights in Canada, op. cit.
9 See DINA, "Statement Made by the Honourable Jean Chretien Minister of Indian Affairs and Northern Development On Claims of Indian and Inuit People", Ottawa: DIAND Communique, August 8, 1973.
10 See Government of Canada, Minutes of Proceedings of the Special Committee on Indian Self-Government, House of Commons Issue No. 40, Wednesday, Oct. 12, 1983 and Thursday, Oct. 20, 1983, Ottawa: Canadian Government Publishing Center, Supply and Services Canada, 1983; and Government of Canada, Living Treaties: Lasting Agreements, Report of the Task Force To Review Comprehensive Claims Policy, Ottawa: DIAND, 1986.
11 Interview with senior Department of Justice, Canada, personnel, who, because of their current involvement in native affairs, prefer to have their names withheld, Ottawa, August, 1984.
12 Interviews held with Negotiators of Land Claims, Department of Indian and Northern Affairs, Ottawa, August, 1984, who preferred anonymity pending completion of land claim settlements.
13 Interview with Agnes Semmler, past COPE President, June, 1986.
14 Committee for Original Peoples' Entitlement, Meetings, Jan. 28, 1970 to 1972.
15 See Roger Gibbins, "The Canadian North In National Perspective", unpublished paper, University of Calgary, 1984.
16 Pimlott et al, Oil Under The Ice, Ottawa: Canadian Arctic Resources Committee, 1976, pp. 135-141.
17 For a detailed summary of identified legal problems which could arise as a result of the Inuvialuit Final Agreement, see Janet Keeping, "Complications of the COPE Agreement", Canadian Institute for Resources Law, University of Calgary, Calgary, 1986, 3 pp.

INUIT FOLK-ORNITHOLOGY IN THE POVUNGNITUK REGION OF NORTHERN QUEBEC

Martha Johnson

Department of Anthropology, University of Toronto, Toronto, Ontario M5S 1A1

Level: Master's

Abstract

The system used by the Inuit of Povungnituk to classify the birds that they are familiar with in their region shows remarkable similarity to the scientific system. There is a recognized hierarchical structure and close correspondence at the species level. In a few instances, an Inuit taxon can be applied to a group of birds which correspond to ornithological genera.

Nomenclature exhibits a number of characteristics in the Inuit classification system. Some names have easily recognizable etymologies and are either onomatopoeic descriptions of the songs of the birds or they describe a salient morphological or behavioural feature of a particular species. Inuit depend upon a variety of criteria to identify birds. This varies according to the individual's knowledge and experience.

There is notable variation in the overall classification scheme. Many taxa are identified by several different names, and hierarchical levels are not always defined consistently. This illustrates the inherent flexibility of the system.

The principles of Inuit classification reflect the knowledge needed by these people to successfully exploit their environment. These findings are in accord with other folk-systematic studies.

Key words: Povungnituk, folk-biology (ornithology).

Résumé

Le système employé par les Inuit de Povungnituk pour classifier les oiseaux de leur région dénote une ressemblance remarquable avec le système scientifique. On y reconnait une structure hiérarchique certaine et une correspondence proche au niveau des espèces. Dans bien des cas, un taxon Inuit qui est appliqué à un groupe d'oiseaux correspond aux genres ornithologiques.

La nomenclature comporte plusieurs caractéristiques dans le système de classification Inuit. Quelques noms ont une étymologie facile à reconnaître; ce sont des descriptions soit onomatopéiques, soit de caractères morphologiques distinctifs, soit de traits de comportement d'une espèce particulière. Les Inuit se basent sur toute une variété de critères pour identifier les oiseaux; ceux-ci peuvent varier selon la connaissance et l'expérience d'un individu.

Cependant, il y a une variation notable dans le procédé général de classification. Beaucoup de taxa sont identifiés par plusieurs noms différents, et les niveaux hiérarchiques ne sont pas toujours consistants. Ceci démontre une certain flexibilité inhérente au système.

Les principes de la classification Inuit reflètent la nécéssité d'une solide connaissance de leur environnement afin de réussir à l'exploiter à bon escient. Ces données se révèlent être en accord avec d'autres études ethno-systématiques.

Mots-clés: Povungnituk, ethno-biologie (ornithologie).

Introduction

Biologists have often remarked on the ability of local natives to distinguish and to name many of the plants and animals in their environment (Hunn 1976). Diamond (1966) in New Guinea, Irving (1960) in Alaska, and Snyder (1957) in arctic Canada, made detailed recordings of the correspondence between the categories of birds named by the natives and the taxa of scientists. A number of systematists have interpreted these findings as support for their views concerning the "reality of species" (Berlin, 1973). Anthropologists on the other hand, have argued that the universe is continuous and order is only something imposed by the human mind — that species do not exist "out there", but only in the minds and writing of zoologists and botanists. Similarly, they have contended, the taxa of folk natural-history are "all in the mind". How can the sets of definitions of preliterate peoples possibly correspond to the sets of definitions of professional scientists which relate to scientific theories (Bulmer, 1970)?

The field of folk-science, of which folk-ornithology is a subdiscipline, examines such questions concerning non-western man's knowledge of the natural environment. A key focus of these studies is folk bio-systematics; the search for the general principles which underlie non-western man's classification, naming, and identification of living things. Each of these areas is tied closely together (Berlin, 1973). In the study of classification, one is concerned with discovering those principles by which classes of organisms are naturally organized in the non-western mind. Nomenclatural studies are devoted to the description of linguistic principles of naming the conceptually recognized classes of plants and animals in some particular language. The area of identification deals with the study of those physical characters utilized when assigning a particular organism to a particular recognized class (Berlin, 1973). In this paper, preliminary findings are presented from a study of Inuit folk-ornithology carried out in Povungnituk, northern Quebec during the spring of 1985. The principles of Inuit bio-systematics for the birds found in the Povungnituk region are examined, and an attempt is made to illustrate the degree of correspondence between Inuit systematics and western science.

Methods

The village of Povungnituk was selected as the area of study because it was familiar to the writer, who had taught high school there the previous year. The community has a population of about 900 people. Most residents live off the land; hunting, trapping, and fishing.

The study consisted of three parts: organization and preparation, interviews, and field work. In preparation, a list based on the Golden field guides was compiled of all the birds known to be present in the Povungnituk region. Several species existing outside the normal hunting range of most people (*i.e.*, the treeline, and the extreme northern coast) were also included in the list in an effort to measure the extent of local people's knowledge and to verify the accuracy of the maps used in the field guides.

Next, a series of thirty-nine interviews was conducted. A random sample was not used. People were selected on the basis of their willingness to do the interviews. However, an effort was made to solicit people of both sexes and different age groups with different amounts of schooling and from different types of employment. Informants were shown a picture of each bird species mounted on small cards and were asked to give the name of the bird, the meaning of the name, and the means of identification; and they were also asked to indicate birds which could be grouped together on the basis of some similarity. In addition, they were asked to provide information about bird habitat, behaviour, mythological significance, medicinal properties, and general utility.

In an effort to obtain a rough census of the birds present in the Povungnituk region at that time of the year, and in order to obtain positive identification of birds by Inuit in their natural setting, the third part of the field study involved a series of camping trips and daily excursions with several Inuit families and a trained biologist.

Classification

Researchers in the field of folk-biology have agreed that the fundamental organizing principle of folk biological classification is taxonomic, whereby recognized groupings (hereinafter called taxa) of greater and lesser inclusiveness are arranged hierarchically (Berlin, 1973). There remains in the literature, however, much debate surrounding the operation of the structure and its characteristic features. According to Berlin, taxa assigned to each of the fundamental folk-biological categories characteristically exhibit linguistic and/or taxonomic features which allow for their recognition. He (Berlin, 1973) recognizes and describes the following ranks in order of decreasing inclusiveness; the Unique Beginner, Life-form, Intermediate, Generic, Specific, and Varietal.

Modifications to the Berlin taxonomic scheme have been proposed by a number of authors.

Bulmer accepts Berlin's hierarchical structure, but he refers to the basic units of folk classification as "speciemes", suggesting that they are formed "by multiple distinctions of appearance, habitat and behaviour" (Bulmer, 1970). In reference to his work among the Karam of New Guinea, he is careful to point out, that "speciemes" are units as Karam themselves see them and that despite the "logical correspondence between the "specieme" and the species of the scientific zoologist, there are instances where the two units diverge (Bulmer, 1970).

Hunn (1977) is similarly in accord with the Berlin structure, but he stresses the importance of psychological criteria in determining the relationship betwen patterns of nomenclature and principles of classification.

In an analysis of Rofaifo mammal taxonomy, in New Guinea, Dwyer (1976) accepts folk taxa irrespective of their nomenclatural or cognitive properties. In contrast to Berlin's approach, which commences with higher order categories and progressively disassembles these to arrive at lower order categories, Dwyer proposes an inverse scheme. He first translates biological species into Rofaifo "species" (in the sense of Bulmer's "specieme") and then works upward from this level through categories of increasing inclusiveness. He claims that, unlike Berlin's method, which imposes a rigid framework of analysis, his system reveals that different categories may be positioned at several conceptual levels.

TABLE 1
Inuit Bird Taxonomy.

Sexual Dimorphism	Scientific Nomenclature	Inuktitut Level 1	Inuktitut Level 2
	Gavia immer	Tuuliq	Tuuliq
	Gavia pacifica	Kallulik	
	Gavia stellata	Qaqsauq	
	Cygnus columbianus	Qutyuq	
	Branta canadensis	Nirliq	Nirliq
	Branta canadensis hutchinsii	Nirlinaaq	
	Anser caerulescens	Kanguq	
Amaulik	Anas acuta	Ivugaq	
Arnaluuq	Aythya marila	Puungalat	
	Somateria mollissima	Mitiq/Mitivik	Mitiq
	Somateria spectabilis	Mitirluk	
Amaulik	Clangula hyemalis	Akiaqanaq	
Arnaluuq	Melanitta nigra	Hirnitakalaq	
	Melanitta fusca	Pitsiulaqpaq	
	Mergus serrator	Aqpangiuk/ Nuyalik	
	Buteo lagopus	Qinuayuaq	
	Aquila chrysaetos	Nuturalik	
	Falco peregrinus	Kikkavik	
	Falco rusticolus	Kikkavik	Aqigik
	Lagopus lagopus	Aqigiviq	
	Lagopus mutus	Nitsatuq	
	Grus canadensis	Tatigaq	
	Pluvialis squatarola	Tulivik	
	Pluvialis apricaria	Tulivik	
	Charadrius semipalmatus	Qulliquliaq	
	Arenaria interpres	Kanakatuq	
	Calidris canutus	Luviluvilaaq/ Sityarialaq	
	Calidris alba	Luviluvilaaq	
	Calidris pusilla	Luviluvilaaq	
	Calidris minutilla	Luviluvilaaq	
	Calidris fusciallis	Luviluvilaaq	
	Calidris melanotos	Luviluvilaaq	
	Calidris alpina	Luviluvilaaq/ Sityariaq	
	Calidris maritima	Luviluvilaaq/ Sityariaq	
	Limnodromus griseus	Sigutuq	
	Gallinago gallinago	Sigutuq	
	Phalaropus lobatus	Saqvaq/ Kaiviquaq	
	Phalaropus fulicaria	Saqpaq/ Kaiviquaq	

TABLE 1
(Continued)

Sexual Dimorphism	Scientific Nomenclature	Inuktitut Level 1	Inuktitut Level 2
	Stercorarius pomarinus	Isungaq/ Kamilik	
	Stercorarius parasiticus	Isungaq/ Kamilik	
	Stercorarius longicaudus	Isungaq	
	Larus philadelphia/ Xema sabini	Nauyarluk/ Nauyaaluk	Nauyaaluk
	Larus argentatus	Nauyaaluk	
	Larus hyperboreus	Nauyavik/ Nauyaaluk	
	Sterna paradisaea	Takatakiak/ Imirkutailaq	
	Uria lomvia	Aqpaq	
	Cepphus grylle	Pitsiulaaq	
	Bubo virginianus	Ukaliatsia-niutiq	
	Nyctea scandiaca	Uppialuk	
	Asio flammeus	Imaingataq	
	Eremophila alpestris	Qupanuaqpaq	
	Corvus corax	Tulugaq	
	Turdus migratorius	Qupanuaraluk	
	Anthus spinoletta	Ingitayuq/ Qupanuaqpaq/ Qupanuaq	
	Spizella arborea	Ukiursiulik	
	Passerculus sandwichensis	Hirnitaaq/ Mitsataaq/ Qupanuaq/ Ingitayuq	Qupanuaq
	Zonotrichia leucophrys	Nasaulik	
	Calcarius lapponicus	Hirnitaaq/ Qupanuaq	
	Plectrophenax nivalis	Amauligaaq/ Qupanuaq	
	Carduelis flammea	Satanasiaraq	

Legend: Named taxa _____
Covert taxa ----------

In this paper, the basic classification system approach of Bulmer (1970) and Dwyer (1976) is used. Inuit perceptions of "speciemes" are accepted as the basic discontinuities in nature. The system of hierarchical organization follows Dwyer's method of starting from the "species" level and working upwards to more inclusive taxa. However, in later sections consideration is given to the significance of nomenclature and identification (psychological criteria) as emphasised by Berlin (1973) and Hunn (1975, 1977).

Table 1 shows that at least 36 taxa which correspond to Bulmer's "specieme" concept are consistently named in the Povungnituk Inuit system of classification. However, in keeping with observations made by Bulmer (1970) and Diamond (1966) of two different groups of people in New Guinea, there are two forms of classification among the Inuit which show divergence from the scientific system.

The first is the recognition of sexual dimorphism in a species. For both *Somateria mollissima* and *Somateria spectabilis*, the species is split into two taxa, the male and the female being called by separate names. In both of these cases, the Inuit are well aware of the biological status of their taxa.

The second instance involves the lumping of two or more distinct biological species into one taxon; *Stercorarius pomarinus*, *Stercorarius parasiticus* and *Stercorarius longicaudus* are all called by the one name "Isungaq". In several cases, Povungnituk informants indicated their awareness of the slight difference in appearance or behaviour of the different *Stercorariidae* species, but affirmed that they were all called by the one name. Other species of birds where this lumping occurs include *Pluvialis squatarola* and *Pluvialis apricaria*, *Phalaropus lobatus* and *Phalaropus fulivaria* and all the shorebirds belonging to the genus *Calidris*.

Following Dwyer's approach (Dwyer, 1976), the hierarchical structure of the Inuit taxonomic system consists of three recognizable levels. Table One shows that Level One consists of the basic folk taxa or "speciemes" (the

subdivision of *Somateria mollissima* and *Somateria spectabilis* is not considered a taxonomic level in the true sense because the biological significance of the category is recognized).

Level Two includes four taxa which include two or more taxa from Level One and are consistently named by two or more informants. These are "Aqigik", "Mitiq", and "Tuuliq". Thus what Berlin *et al.* (1973) refer to as a "covert category" may also be present in the case of the grouping of Level One, *Branta canadensis*, and *Branta canadensis hutchinsii* (probably the subspecies in the region). Several informants indicated simply that "Nirliq" and "Nirlinaaq" "belong together", but that there is no specific name used to identify this grouping.

There are two ambiguous taxa located in Level Two. Three informants indicated that the taxon "Qupanuaq" refers to a category including *Calcarius lapponicus* and *Plectrophenax nivalis*. Four other informants claimed that it refers to these two species as well as to all of the "sparrow-like birds" (*Anthus spinoletta, Spizella arborea, Zonotrichia leucophrys, Carduelis flammea*). The name "Qupanuaq" can also be applied individually to any of the small "sparrow-like birds" at Level One, although this appears to be more the case among younger and less experienced informants.

Similarly, the name "Nauyaaluk" may be applied to either *Larus argentatus* or to *Larus hyperboreus* at Level One, or at Level Two it may include these two species plus another species of *Larinae* identified as occurring occasionally in the region (people may be referring to *Xema sabini, Larus philadelphia*, or an immature of one of the above species).

It appears that the Inuit system of bird classification is like that of many other non-western peoples and is based on the principle of hierarchy. It also shows some divergence from the scientific system and inconsistency in the structure of its categories.

Nomenclature

As noted earlier, Berlin (1973) claims that there is evidence from a number of folk-biological studies of a fairly close correspondence between the linguistic form of a name for some folk biological taxon and its hierarchical rank (Berlin, 1973).

According to Berlin (1973), etymologically it is often impossible to provide linguistic analysis of either life-form or generic names because of their antiquity. When analysis is possible, it is often the case that the name is descriptive of some quality of the class of organisms to which it refers.

This observation is evident in the Povungnituk bird naming process. A number of the bird names have easily recognized etymologies. For example "Nuyalik" (*Mergus serrator*) means "the one with hair" and "Kamilik" (*Stercorarius pomarinus* and *Stercorarius parasiticus*) means "the one with boots'. Other names describe some behavioural characteristic; "Kaiviquaq" (*Phalaropus lobatus* or *Phalaropus fulicaria*) means "the one that spins", "Aqpangiyuk" (the more common name for *Mergus serrator*) means "the one that runs on water".

However, in the majority of cases, people indicated that they did not know the meaning of the names. Most of them would seem to be quite ancient in origin and in fact are recognizable in a similar form across the Arctic (Irving, 1960; Snyder, 1957).

Berlin (1973) notes that onomatopoeia is also important in the formation of many generic names. Such is also the case for Povungnituk. Many of the names are onomatopoeic descriptions of the bird. E.g., "Qaqsauq" refers to the call of *Gavia stellata*, and "Qulliqulliaaq" is the call made by *Charadrius semipalmatus*.

A final linguistic feature which Berlin (1973) claims is widespread in many languages is the use of the "generic" plus some modifier to refer to some taxon that is conceptually related to the class indicated by the generic name alone. In Povungnituk, one such instance occurs in the case of "Nirliq" (*Branta canadensis*) and "Nirlinaaq" (*Branta canadensis hutchinsii*). "Nirlinaaq" is described as being "like a 'Nirliq'".

In many instances, two or more names are given to each species. Table 1 illustrates the species that have at least two names consistently applied to them. In the case of *Sterna paradisaea*, several informants indicated that "Takatakiak" is a name employed by younger people (probably onomatopoeic), while "Imirkatailaq" describes the forked shape of the tail. In other instances, people applied a Level Two name to a particular bird species in Level One; thus, "Mitiq" is often used to refer to the *Somateria mollissima*, "Aqigik"' refers to both *Lagopus lagopus* and *Lagopus mutus*. "Nauyaaluk" and "Qupanuaq", as noted earlier, may refer to any of the birds belonging to the Subfamily *Larinae* and the Order *Passeriformes* respectively. A number of other researchers have similarly remarked on the occurrence of this multiple naming process (Hunn, 1977; Gardner, 1976; Kesby, 1979).

When Inuit are discussing taxonomic groups belonging to Level Two, they usually take the largest and/or the typical species as the reference point for comparison, (*i.e.*, "Mitiq", "Tuuliq" and "Nauyaaluk"). The name "Timiaq", which comprises Level Three, means "things that fly". Although it includes only organisms which belong to class *Aves*, this name is also used to designate airplanes.

It appears that the Inuit system of naming taxa shares many similarities with those of other non-western people. There is considerable variability at each level of the taxonomy and several of the linguistic characteristics observed by Berlin are also evident in the Inuit system.

Identification

Hunn (1975) contends that, by analyzing the identification process, we are able to understand more fully the process of classification and to explain the variation present within a culture in conceptions of taxonomic structure. In his opinion,

> Informants do not readily verbalize criterial features of most biological taxa, perhaps because such taxa are conceptually 'primitive', *i.e.*, they are not definable in terms of concatenations of conceptually prior 'givens'. Rather, it seems likely that such taxa are best characterized as defined by a

> single complex pattern or 'gestalt', abstracted automatically from each perceived image, rather than as a set of values of several discrete dimensions of contrast or 'features' (Hunn, 1977).

Similarly, Bulmer contends that for the lowest order taxa of classification,

> each is not only distinguished by its appearance, but implicitly at least by the fact that it has a distinctive way of life. They are 'natural' units, not the arbitrary end-product of a system of human classification which reduces the universe to minimal manageable units by a simple process of imposing a series of binary operations'' (Bulmer, 1970).

Ellen (1979a) supports Hunn and Bulmer's notion of a configuration of featues defining a category. He adds that the definitive attributes chosen may in fact keep changing, depending upon the individual and the elicitory context.

Turning to the Inuit process of identification, the most common response to the question, ''How do you identify species ''X''?'' was, ''the way it looks''. In some instances, informants referred to an aspect of appearance: size, colour, or shape. Attribute selection varied according to the taxa identified and according to the individual. In the case of species with a particularly salient feature (*e.g.*, the tail of *Clangula hyemalis* and *Anas acuta* or the crown of the *Mergus serrator*), these were given as the discriminating features. Distinctive sounds, often corresponding to birds with onomatopoeic names (*e.g.*, ''Luviluvilaaq''), and distinctive aspects of bird behaviour, such as the spinning action of *Phalaropus lobatus* and *Phalaropus fulicaria*, the nocturnal habits of *Asio flammeus*, and the diving motion of *Aythya marila*, were also acknowledged to be distinguishing characteristics. In most cases, people also gave a general description of the habitat when questioned about it (*e.g.*, ''it is found around cliffs'', ''it is found near small ponds'', ''it is found along the sea coast''). However, except in the case of shorebirds, habitat was generally not the most common means of identification. As might be expected, those individuals with a greater knowledge of birds in general gave a combination of several features to identify a particular taxon.

It appears that no single feature is essential for membership in a particular taxon, nor is any feature sufficient for membership. Rather, as has been suggested by the above authors, distinction of fundamental taxa (*i.e.*, those corresponding to biological species) is based on an image of the bird as a whole, supplemented by salient morphological characteristics, sound, behaviour, and habitat.

Identification of Level Two birds appears to be based upon similar principles. Level One taxa which are grouped together at Level Two all share common morphological, behavioural, and habitat characteristics.

Correspondence of folk and scientific classification

Can folk and scientific systems of classification be compared? Despite a growing body of evidence that suggests that the fundamental taxa recognized in folk-systematics correspond fairly closely with scientifically known species (Berlin, 1973), a number of anthropologists argue that the two systems are predicated on different principles (scientific systematics being based on evolutionary theory) and therefore cannot be compared (Bulmer, 1970).

Hunn (1975) points out that our present biological taxonomy, in its earliest form, was simply the folk system current in medieval Europe stretched to accommodate organisms brought back from all parts of the world. Hunn argues that the vast majority of folk categories of plants and animals described seem to be generated by primary attention to morphological and behavioural characteristics intrinsic to the organisms classified. Citing the well known taxonomist, G.G. Simpson, Hunn claims that bio-systematics employ a similar strategy in classifying living organisms: ''among a number of species some will resemble each other more than others. It is to be assumed that the resemblances, as far as homologous, reflect propinquity of descent'' (Simpson, quoted in Hunn, 1976). In the case of hierarchic structure, Hunn (1976) points out that, although the depth of hierarchy found in folk systems nowhere approaches that of the scientific system, no folk systems deal with the same numbers as the scientific system.

One of the difficulties in any comparison concerns the units of analysis to be considered. In the case of western systematics, it is clear that the selection of the basic unit is the species (Berlin, 1973).

In folk systematics, the unit favoured by Berlin (1973) is the folk ''genus'', which corresponds to the smallest discontinuities in nature. He claims that one can recognize at least three logical types of correspondence between the two systems. These include one-to-one correspondence, over-differentiation, and under-differentiation.

Following this method, the Inuit and the scientific system are compared.

For the first type of mapping, one-to-one correspondance whereby a single folk generic (corresponding to a ''specieme'' in Level One) taxon refers to one and only one scientific species, 30 instances out of a total of 36 taxa can be observed in the Inuit system. For example, the taxon ''Tuuliq'' would be in a one-to-one correspondence with the zoological species *Gavia immer*.

Over-differentiation can be observed when two or more folk generic taxa refer to a single scientific species. Berlin notes that, for his Tzeltal studies, this type of mapping has a quite low occurrence, and he predicts that it will be rare in other folk taxonomies as well. The only instance of this occurring in the Povungnituk Inuit taxonomy is the distinction made between the male and female of *Somateria mollissima* and *Somateria spectabilis*. However, in each case where a person pointed out the two categories, they were aware of the biological significance of them.

Under-differentiation can be divided into two types. Type One under-differentiation occurs when a single folk generic taxon refers to two or more scientific species of the same genus. The Inuit ''Isungaq'' or ''Kikkavik'' would exemplify this type of mapping. In all, there were four instances of this occurrence.

Type Two under-differentiation is recognized when a single folk generic refers to two or more species of two or more scientific genera. This case is illustrated by the Inuit "Sigutuq", which refers to two species of the two scientific genera, *Limnodromus* and *Gallinago*. A total of two cases were present.

Level Two most closely resembles the genus level in the western scientific system. All of the birds represented in the Inuit taxa "Tuuliq", "Mitiq", "Nirliq", "Agigik", and "Nauyaaluk" (if "Nauyarluk" proves to be *Larus Philadelphia* and not *Xema sabini*) belong to the same genus. In the case of the Inuit taxa "Qupanuaq", it may refer to two different genera if *Calcarius lapponicus* and *Plectrophenax nivalis* make up the category. However, it may crosscut at least seven different genera if it encompasses all the "sparrow-like birds".

Discussion

Why have Inuit developed such a detailed classification of birds that appears to have a high level of correspondence to the scientific system? In partial answer to this question and in reference to his studies of the Karam of New Guinea, Bulmer (1970) argues that Karam zoological classification, at the lowest level, is concerned with objective discontinuities in nature.

> Thus, as far as wild fauna is concerned. . ., they are not only applying units which are in the logical sense "species", but they are concerned with, and to a large extent aware of, the discontinuities which define biological species, even where their folk-taxa do not correspond one-to-one to these" (Bulmer, (1970).

Furthermore, he contends:

> Any human population which gets its living by direct exploitation of natural resources, whether by hunting and gathering, agriculture, fishing or pastoralism, is forced to meet nature on its own terms and to categorize those aspects of the natural environment which are relevant to it in a biologically realistic way" (Bulmer, 1970).

A number of biologists and anthropologists (Berlin, 1973; Bulmer, 1970; Diamond, 1966) have noted the importance of culture in defining a classification system. For example, species which are valued for their food, feathers, or skin will be more finely distinguished than those which are less significant. As noted earlier, most of the Level Two groupings exhibit this quality.

On the other hand, as Diamond (1966) remarks in his study of the Fore of New Guinea, even small, drab birds are recognized as separate taxa. He suggests that this feature may be an economic relic of disappearing food habits. In Povungnituk, many of the older informants indicated that almost all species provided food at some time in the past during periods of hunger. Diamond contends that these fine taxonomic distinctions may also be because such species have calls and habits, which a hunter must learn to recognize in order to guide himself in his choice of prey.

It was remarked earlier that each taxon as developed by the Povungnituk Inuit is often identified by several different names, and there is often ambiguity in distinguishing taxa at higher levels in the taxonomy. This is perhaps not surprising, given that individuals vary in their experience and knowledge. As Kesby (1979) noted in his studies of Rangi bird classification in New Guinea, "All Rangi could put creatures into the major categories in which they belonged, but many were unable confidently to put a name to every animal or plant which they saw".

In another study of the Nuaulu of eastern Indonesia, Ellen (1979b) stresses the role of literacy and the purpose of classification systems.

> "Scientific classifications are developed by specialist groups in society for a highly esoteric purpose - the pursuit of knowledge itself. Folk classifications are generally not the product of groups of specialist minds, and must have general cognitive and social utility" (Ellen, 1979:23).

Ellen (1979b) points out that, in a culture based primarily on oral tradition, such as the Inuit, the entire content of cultural tradition, except artefacts, is held in memory. Once writing is adopted, new types of graphic form and means of organizing communication are introduced which may be critical in determining classificatory activity.

Conclusion

The Inuit of Povungnituk recognize objective discontinuities of their natural environment. This is in accord with the findings of other folk-systematic studies. There is significant similarity between the Inuit and the scientific system, but there is also divergence. Variation in the system appears to represent its inherent flexibility. The principles of Inuit classification reflect the knowledge needed by these people to successfully exploit their environment. The extent of their actual knowledge goes well beyond the needs of classification and is truly impressive to the outsider.

Acknowledgments

The writer would like to thank the Association of Canadian Universities for Northern Studies, the Arctic Institute of North America and Indian and Northern Affairs Canada for their generous financial support in this project.

A special thanks to the people of Povungnituk, northern Quebec, whose patience and helpfulness made this project possible.

References

Berlin, B. 1973. Folk systematics in relation to biological classification and nomenclature. Annual Review of Ecology and Systematics 4:259-271.

Berlin, B., Breedlove, D.E., and Raven, P.H. 1973. General principles of classification and nomenclature in folk biology. American Anthropologist 75:214-242.

Bulmer, R.N.H. 1970. Which came first, the chicken or the egghead? In Pouillon, J. and Maranda, P., eds. Échanges et communications, mélanges offerts à Claude Levi-Strauss à l'occasion de son 60-ème anniversaire. The Hague: Mouton. 1069-1091.

Diamond, J.M. 1966. Zoological classification system of a primitive people. Science 151:1102-1104.

Dwyer, P.D. 1976. An analysis of Rofaifo mammal taxonomy. American Ethnologist 8:425-443.

Ellen, R.F. 1979a Omniscience and ignorance: Variation in Nuaulu knowledge, identification and classification of animals. Language and Society 8:337-364.

———— 1979b. Introductory Essay. In Ellen, R.F. and Reason, D., eds. Classifications in their Social Context. New York: Academic Press. 1-29.

Gardner, P.M. 1976. Birds, words and a requiem for the omniscient informant. American Ethnologist 8:446–468.

Hunn, E. 1975. Cognitive processes in folk-ornithology: The identification of gulls. Language-behavior Research Laboratory, University of California (Berkeley). Working paper No. 42. 73 p.

_____ 1976. Toward a perceptual model of folk biological classification. American Ethnologist 8:508–522.

_____ 1977. Tzeltal Folk Zoology: The Classification of Discontinuities in Nature. New York: Academic Press. 368 p.

Irving, L. 1960. Birds of Anaktuvuk Pass, Kobuk, and Old Crow. Washington D.C.: United States National Museum. Bulletin 217. 409 p.

Kesby, J.D. 1979. The Rangi classification of animals and plants. In: Ellen, R.F. and Reason, D., eds. Classifications in their Social Context. New York: Academic Press. 47–54.

Snyder, L.L. 1957. Arctic birds of Canada. Toronto: University of Toronto Press. 310 p.

NATIVE RIGHTS AND LIBERALISM

William Kymlicka

Department of Philosophy, Queen's University, Kingston, Ontario K7L 3N6

Level: Ph.D.

Abstract

It is generally accepted that political institutions and boundaries in the north should be changed to be more responsive to the needs of the aboriginal population. However, many proposed changes have been criticized as "illiberal" in that they recognize certain collective rights of the Dene or Inuit. Liberalism, it is said, is about treating individuals as equals, and it is a betrayal of that fundamental principle if we allow rights and benefits to be distributed on the basis of race and cultural membership. The requirements of liberal equality conflict with, and perhaps outweigh, any claim stemming from aboriginal status. Measures that would protect native culture by limiting the mobility or voting rights of non-natives are said to be politically regressive and pernicious, since they create two classes of citizens, the first step on the road to apartheid. But these complaints and fears are misguided — many of the collective rights embodied in the Inuit and Dene proposals are not only consistent with, but required by, the principles of liberal equality, and by the liberal concern for individual autonomy. Individuals' choices always occur within a cultural context — a shared structure of language and history. For whites, that context is always secure, but the continued existence of native cultures in the north depends on them not being outvoted on certain issues, or outbid on certain resources. This concern for the cultural context within which natives make choices isn't in conflict with the liberal concern for individual freedom and equality — on the contrary, they presuppose each other.

Key words: Northern policy and planning, Nunavut, aboriginal rights, cultural conflict.

Résumé

On reconnaît en général qu'il faut changer les institutions politiques et les limites administratives dans le Nord canadien, pour les rendre plus sensibles aux besoins de la population autochtone. Cependant, certains ont critiqué les modifications proposées parce qu'elles évoquent des tendances collectivistes, en accordant certains droits collectifs aux Dene ou Inuit. Le libéralisme propose de traiter les individus sur une base d'égalité, et ce serait trahir ce principe fondamental que de permettre une répartition des droits et des avantages sur la base de l'appartenance raciale ou culturelle. Le principe de l'égalité des individus s'oppose à toute revendication fondée sur le statut d'Autochtone, et peut-être prévaut contre elle. Les mesures de protection de la culture autochtone par la limitation de la mobilité des non-Autochtones ou de leur droit de vote sont, dit-on, un retour en arrière, et malsaines sur le plan politique, car elles instituent deux classes de citoyens, première étape vers un régime d'apartheid. L'auteur estime que ces objections et ces craintes sont mal fondées, car de nombreux droits collectifs incorporés dans les Propositions des Inuit et Dene sont non seulement conformes aux principes libéraux d'égalité et de droit individuel au choix, mais aussi exigés par ces principes. Les choix individuels sont toujours exercés dans un cadre culturel, contexte historique et linguistique commun. Pour les Blancs, ce contexte est toujours présent; par contre, la pérennité de la culture des autochtones dans le Nord depend de leur prépondérance électorale en certains domaines, ou à l'égard de certaines ressources. Cet accent donné au cadre culturel du choix des autochtones ne contredit pas les principes libéraux de liberté et d'égalité des individus; au contraire, ils se présupposent réciproquement.

Mots-clés: Politique et prospective nordiques, Nunavut, droit des Autochtones, conflits interculturels.

Native rights and liberalism

Native rights for the aboriginal population of Northern Canada have been on the political agenda for over a decade, ever since Thomas Berger recommended that the Mackenzie Valley pipeline not be built until native land claims are settled (Berger 1977). But the debate continues over the proper nature and scope of these claims. Certainly natives ought to be able to run their own lives, free from the paternalism and exploitation that has characterized white-native relations in the past. No one disagrees with that, at least not openly. But there has been intense opposition to many of the more comprehensive proposals for native self-government. Everyone agrees that natives shouldn't suffer legal discrimination or disabilities, and that legitimate land claims ought to be recognized, but it is quite another thing to accept that natives should have special political rights, or a special political jurisdiction, especially where this would involve limiting the mobility and voting rights of non-natives. Some people are only willing to offer what the natives consider to be token measures of self-government — the devolution of power from Ottawa or Yellowknife, for example, in areas of local concern, such as health, education and housing, but not the sort

of broader economic and political power that the natives feel is necessary to ensure that native communities continue to survive as self-determining cultural communities. Native groups want the power to veto land uses which threaten their communities, even if these land uses are favoured by a non-native majority, either in the North or in Canada at large.

What is the source of the opposition to these more comprehensive self-government claims? One source is unquestionably the self-interest of non-natives — Wayne Haimila has shown how support for the native claims slipped significantly when it was realized that they could jeopardize economic development in the north (Haimila 1978). But there is another, and perhaps more important, source of opposition. The very idea of group rights runs counter to the dominant "ideology" of our society, the dominant political morality underlying our political practice and institutions — namely, the ideology of liberalism. To be a liberal, in this context, doesn't necessarily mean being a member of the Liberal Party. Liberalism, in this sense of ideology or world-view, is a pervasive aspect of much of English-Canadian culture, and is present in the thinking of all three of the major political parties (e.g. Ponting and Gibbons 1980, 331). Liberalism is characterized both by a certain kind of *individualism* — that is, individuals are viewed as the ultimate, and indeed the only, units of moral worth, the only things with any ultimate moral standing; and by a certain kind of *egalitarianism* — that is, every individual has an equal moral status, and hence is to be treated as an equal by the government, with equal concern and respect (Dworkin 1983, 24; Rawls 1972, 511). Since individuals have ultimate moral status, and since each individual is to be respected as an equal by the government, liberals demand that each individual have equal rights and entitlements. Liberals have disagreed amongst themselves as to what these rights are, because they have different views about what it means to treat people with equal concern and respect. But most would accept that these rights include rights to mobility, to property, and to political participation in one's community. The new Canadian Charter of Rights and Freedoms embodies these liberal principles, guaranteeing such rights to every citizen, regardless of race, or sex, or ethnicity, or language etc. These principles, and similar ones in the older Canadian Bill of Rights, have been used to strike down legislation concerned with group rights for natives in the north. Similarly, the 14th Amendment of the American Constitution, guaranteeing equal protection of the law to all its citizens, was used to strike down segregationist legislation that set blacks apart in the American south. The logical conclusion of these liberal arguments or principles is what's called a "colourblind" constitution — the removal of all legislation differentiating people in terms of their race or ethnicity. This was explicitly the motivation behind Trudeau's "White Paper" policy of 1969 (DIAND), designed to terminate the special status of natives in Canada, and liberals have only reluctantly retreated from it, despite the almost unanimous opposition it received from the natives themselves. Their reluctance stems from the fear that any deviation from the strict principle of equal individual rights will be the first step down the road to apartheid, to a system where some individuals are viewed as first-class citizens and others only second-class, by virtue of their racial or ethnic affiliation. These fears are strengthened when liberals see white South African leaders invoke "minority rights" in defense of their system of apartheid, and complain about "Western hypocrisy" in criticizing their system of tribal homelands while allowing reservations for North American natives (International Herald Tribune 1985, 2; Toronto Star, 1986, B3). Many commentators have argued that this liberal antipathy to group rights has been the biggest stumbling block to a satisfactory settlement of native claims (Weaver 1981, 55, 196; Ponting and Gibbons 1980, 328–330; Asch 1984, 76–87, 100–103; Dacks 1981, 64–79).

What arguments can we give in defense of native self-government, when confronted by this opposition? There may not be very much we can say to those who are unwilling to compromise their material self-interest. But against liberalism, three arguments have commonly been advanced to show why the requirements of liberal equality are *inapplicable* to the situation of natives in the north. I want to just briefly mention these, and some liberal objections to them, before moving on to a different and less common defense of native rights — namely, one that rests not on values that compete with liberalism, but on the very values that liberals claim to be pursuing.

The first argument for the inapplicability of liberalism centers on the fact that the natives were here first, and so have certain aboriginal or treaty rights which are ignored by liberalism (Cardinal 1969; Dene Nation), including the right to self-government. Certainly it is true that non-natives used illegitimate means to gain economic and political power over land originally occupied by natives. But on the other hand, it is equally true that many native groups used force and fraud to gain power over territory which was originally held by other native groups (Crowe 1974, 53–54; Ewers 1981). If Chipewyan Indians can come to have legitimate title and power over territory forcibly taken from the Dogrib or Hare, why can't the Hudson's Bay Company come to have legitimate title over territory forcibly taken from the Chipewyan? Perhaps some of you will respond that the Chipewyan shouldn't be given self-government in these circumstances — perhaps we have to look through the historical evidence, in each case, to see if the native group in question really was the first one there, and never used any force in acquiring that territory. But the liberal responds that this search for some ultimate and pure original title is not only impossible but unnecessary. As Trudeau said when asked what he would do to correct the historical injustices committed against Canada's natives:

> "I can only say as President Kennedy said when he was asked what he could do to compensate for the injustices that the Negroes had received in American society: "we will be just in our time". This is all we can do. We must be just today."
>
> (Ponting and Gibbons 1980, 28)

The second argument centers on the different value systems of native peoples — as a spokesperson for the Metis and Non-Status Indians Constitutional Review committee put it:

> "The value system of the dominant socio-cultural system of Canada is liberalism which places emphasis in the individual, individual rights and private property. This is in contrast to the value system of Native peoples which places a far higher value on the collectivity or upon the community"
>
> (Ponting and Gibbons 1980, 28)

Liberalism, with its individualism, ignores the value community has to native individuals — individual rights are less important to them than collective rights, for example. But this rests on a misunderstanding of liberalism. Liberalism doesn't tell individuals to be selfish rather than communal, or to be indifferent to the fate of their own community. Rather it says that individuals should be free to *choose* what it is they value. If they choose to pool their effort and resources with other members of their culture, then they should be free to do so. Liberalism is precisely concerned to ensure that each individual is able to make such choices — that is why each individual is to be guaranteed both equal resources and equal liberties with which to make such choices. It seems a rather misplaced criticism of this to say that natives care much more than non-natives about communality — nothing whatsoever prevents native individuals from choosing communal ways of life. All that liberalism prohibits is anyone trying to prevent others from having their share of resources or liberties to lead their lives. Nothing in this argument about different value systems explains why native groups should have "special status" in terms of resources or political powers, or why anyone has a legitimate complaint against a scheme of equal rights. As William Wuttanee, one of the very few native leaders who endorsed Trudeau's 1969 policy, said — are natives a distinct community by choice or by law? If it's by choice, because they value such a collective existence, then they should have no complaint against liberal equality, for it allows them to make precisely such choices in accordance with their values (Wuttanee, 1971). Liberalism allows that every individual can lead their life in accordance with their own values, so long as they respect the right of other people to do the same. Unless natives are willing to say, and justify the claim, that certain people count for more than others, then the fact that different groups have different value systems doesn't explain why we should deviate from an egalitarian distribution of rights and resources.

One can attack the "individualism" of liberalism in a deeper way, by claiming that groups in and of themselves have moral status. This third argument against liberalism centers not on the fact that community matters more to native individuals than to non-native individuals, but on the idea that community matters independently of how much it matters to individuals. Perhaps liberalism can account for the importance of community in the lives of native individuals, but individuals are not the only things with moral status or moral claims. Groups, too, historical cultures, have a moral importance which goes beyond the value they have for their individual members, and hence they have legitimate moral claims. For example, groups have the right of survival. Ponting and Gibbons discuss and lament the fact that, in the conflict between individual equality and collective survival, the White Paper "came down on the side of equality. The rights of the individual were placed above the collective survival of the group" (Ponting and Gibbons, 1980, 27). Gurston Dacks talks about "the primacy of the group and its need for self-determination" (Dacks, 1981, 78). But it seems very implausible that the group has a "need" for either survival or self-determination — groups just don't have needs. They aren't the right sort of being to have moral status. It's individuals whose lives go better or worse, and so it is their welfare which is the subject matter of morality, not the metaphorical "needs" or "rights" of groups. Most of us would accept that the only moral value in the world is that which comes from the value of human lives — indeed, nothing else seems intelligible. It seems perverse to suppose that individuals, who are the only beings that really suffer or flourish, can legitimately be sacrificed to further the "needs" of something which is incapable of ever suffering or flourishing. The only thing that matters is human beings, and since every individual matters equally, from the moral point of view, any acceptable and intelligible defense of group rights must show how they play a role in treating people as equals.

Perhaps you disagree. But the fact that many people find the idea of groups having moral status not just wrong but incomprehensible raises a very important political point about all three of these arguments against liberalism. Even if they aren't as philosophically weak as I have suggested, they are very weak *politically* — for they don't give the *liberal* any reason to support native self-government. For example, none of them gives any very clear explanation of why collective rights *aren't* the first step on the road to apartheid. Opponents of liberalism may find them convincing, but they aren't the ones who need convincing on this matter. Perhaps groups do have some legitimate moral status that I just can't see, but it would be better to find reasons for native rights that liberals can see, that are consistent with their moral principles. Best of all would be an argument which showed why native self-government was not only *consistent with*, but *required by*, liberal principles. Native rights would be more secure if they weren't viewed as competing with liberalism, but as an essential component of liberal political practice.

How would such an argument go? Liberalism, as I mentioned before, says that individuals matter, they matter equally, and they are all that matter. But what is the nature of the individual in liberal theory — how is he or she conceived, and hence how is his/her life supposed to go better or worse? In essence, the individual is viewed as a conscious and purposive agent — that is, he/she acts to achieve certain goals or purposes, based on beliefs they have about what is worth achieving, having or doing. It is these beliefs which give meaning to our lives — make sense of why we do what we do. But of course, we may be wrong about these beliefs — we may come to question the value or worth of many of the things we do — watching sports on TV, going to church on Sunday, or even participating in academic conferences. Because these beliefs underlie the most important choices in our lives, and because we care whether they are true or false, liberals claim that each individual should have the guarantees of personal independence needed to freely decide for themselves what is valuable in life. People should be free not just to act in accordance with their current religious beliefs, for example, but also to question these beliefs, and to adopt other beliefs, without being deprived of their liberties, or their resources, without being penalized or discriminated against by society (Rawls, 1972, 209, Dworkin, 1983, 24–30).

To treat everyone as equals, then, means securing for each individual the liberties and resources necessary to examine and act on beliefs about what gives value to life, free from coercion or economic deprivation or systematic distortion of information. The idea of seeing the value of our activities is very important — its crucial to what John Rawls calls self-respect — i.e. the sense that one's plan of life is worth carrying out, and that we have the ability to carry it out. Self-

respect, as Rawls says, isn't so much a part of any rational plan of life but rather a *precondition* of it — if we thought that we were incapable of achieving our goals, or that our goals weren't worth pursuing, then there would be no point to our activities. To ensure that we have this self-respect requires having the conditions to examine one's beliefs, to confirm their value, and the resources/liberties to act on them (Rawls 1972, 178).

So far, that seems unobjectionable. But we need to look more closely at this idea of certain beliefs about value giving meaning to our lives. Where do these beliefs come from? Certainly we should be free to accept or reject particular options presented to us — so ultimately, the beliefs we continue to hold are the ones we've *chosen* to accept. But the options can't be chosen. They are presented to us by our culture, and our heritage, our education and upbringing. The decision about how to lead our lives should ultimately be ours alone, but this decision is always a matter of selecting what we believe to be most valuable from the various options available, selecting from a *context* of choice, a context which provides us with different ways in which to make our lives meaningful.

That sounds quite banal, but is of the utmost importance. For different courses of action, different patterns of physical movements, as it were, only have meaning to us because they are identified as having significance by our *culture* — if they fit into some *pattern* of activities which can be recognized as a way of leading one's life. To use the concepts of semiotics, certain actions are 'signified' by particular words or symbols, and this involves having a place in the larger *system* of signification. Or to use the concepts of social psychology, we can talk not about the signification of social activities, but of "role-models" — certain activities have significance because they are part of particular "models" that are present in our cultural heritage. We become aware of them by their presence in certain stories or tales we've heard about the lives, real or imaginary, of others. Alasdair MacIntyre says that all of us make decisions about how to lead our lives by "situating" ourselves in certain "narratives", narratives which we hear as children in the form of cultural legends, family tall-tales, or religious parables. We decide how to live by adopting some role that has struck us as a worthwhile one, as one worth living (MacIntyre 1981, 200–206). These processes by which options and choices become significant to us are *linguistic* and *historical* processes. Whether or not a course of action has any significance for us depends on whether, or how, our *language* renders vivid to the individual the point of that activity. And the way in which language renders vivid these activities is a matter of our cultural heritage, or history. This is why Northrop Frye has recently defined a culture as "a whole lifestyle of a people, starting with the language they speak" (Sparham 1978, 335). One's language and history are the media through which we come to awareness of the options available to us, and come to see their significance, their purpose. Understanding, in this way, the point of various activities is a crucial precondition to making intelligent judgments about their worth. In order to make intelligent judgments about how to have a meaningful life, we explore not a number of different patterns of physical movements, which might in principle be judged in abstraction from any cultural structure, but precisely by examining this cultural structure, by coming to an awareness of the possibilities it has, the different activities it identifies as significant, as parts of narratives. We then have to make judgments about what is worth doing with our lives, but the *context* of these decisions is always the cultural structure in which the different options acquire significance to us.

What follows from this? Liberals should be concerned with the fate of cultural structures, not because they have some moral status of their own, but because it's only through having a rich cultural structure that people can become aware, in a vivid way, of the sorts of options available to them, and intelligently examine their value. Without such a cultural structure, children and adolescents lack adequate role models, resulting in despondency or escapism — a condition poignantly described by Allan Seltzer in a recent article on the adolescents of some Inuit communities (Seltzer 1980).

But why does this matter for policy in the North? People may require a cultural structure to make sense of their lives, but it doesn't yet follow that we ought to take special measures to protect their own culture. Why not just assist natives in moving to English Canada and learning English? But we can't just transplant people from one culture to another, even if we provide the opportunity to learn the other language and history. For one thing, one's upbringing isn't something that can just be erased — it is, and always remains, a constitutive part of who we are. One's language isn't just a neutral medium for identifying the content of certain activities, it "itself *is* content, a referent for loyalties and animosities" a "marker of . . . the societal goals the large-scale value laden arenas of interaction that typify every speech community" (Fishman 1972, 4). And so language and cultural identity become a part of our personal identity, and a source of strength and self-respect. People do not just ask if they face a rich context of choice in which they are linguistically competent, but also whether it is *their* culture — and their sense of personal competence seems to be tied up with the answer to that question. Someone stripped of his/her cultural heritage is likely to suffer psychic damage, even if he/she is then put into a cultural context with equally rich opportunities in which he/she is linguistically competent. This connection between cultural heritage and the sense of moral agency is revealed in the following quote from F. Mkhwanazi, a black South African:

> the regime tried to make us believe that our people had no history . . . they wanted us to carry an image of ourselves as pathetic, utterly defeated, dependent, incapable and powerless.
>
> (Mkhwanazi 1985, 18)

Harold Cardinal makes a similar point in discussing the way whites denigrated the Indian cultural heritage as part of their "pacification programme" (Cardinal 1969, 53). But this strategy, pursued all-too-successfully by racist and oppressive regimes around the world, only makes sense if one's sense of moral agency is tied to one's cultural heritage. Why else would telling an individual that his/her *people* had no history have the effect of giving the individual an image of *himself/herself* as powerless? This suggests that cultural structure is not just crucial to the pursuit of our chosen ends, but also to the very sense that we are capable of pursuing them efficiently.

Self-respect requires respect for one's heritage and community membership. This is why group rights for natives differ from segregation of blacks in the American south. Liberals opposed segregation because it was viewed as a "badge of inferiority" by the blacks, a refusal to acknowledge the equal worth of the black community. Many liberals — too many — have simply assumed that the way to show respect for the native community is to attack segregation here. The crucial difference is, of course, that natives *want* to be a distinct community. It is sometimes forgotten that the Supreme Court rejected "separate but equal" not on any universal grounds, but because in the *United States* in the *1950's* segregation was perceived as a "badge of inferiority". The lower motivation of black children in their segregated schools was a crucial factor in the Court's decision. But in Canada, segregation has always been viewed as a defense of a highly valued cultural heritage — while there are no special problems about motivation on segregated reserve schools, the drop-out rate for natives in integrated high schools was over 90%, and in most areas was 100% for post-secondary education (Ponting and Gibbons 1980, 55–58; Gross 1973, 237–242). Michael Gross argues that since the "integration of Indian children in white-dominated schools had the same negative educational and emotional effects which segregation was held to have in 'Brown', therefore the "underlying" principle" which struck down legislated segregation of blacks (i.e. that racial classifications harmful to a racial minority are unconstitutional) would also strike down legislated integration of Indians" (Gross 1973, 245). Assimiliation for the natives, like segregation for the blacks, is a "badge of inferiority" which, in the words of a Senate Subcommittee, "fails to recognize the importance and validity of the Indian community" and which results in a "dismal record" of "negative self-image and low achievement" as "the classroom and the school [become] a kind of battleground where the Indian child attempts to protect his integrity and identity as an individual by defeating the purposes of the school" (Gross 1973, 242). Similar problems arise if natives have to assimilate later in life — e.g. at work.

So there are important differences between the case of blacks in the South and natives in Canada, differences which are often ignored by Canadian liberals. But nothing yet shows why anyone has a legitimate complaint against an egalitarian distribution of rights and sources — as we've seen, liberalism is meant to be able to accommodate the fact that different groups value different things. Why should natives have more than an equal share in pursuing the things they believe to be valuable? Part of our complaint is, of course, that natives *don't* have an equal share of social resources. But that complaint is more about our failure to live up to the ideals of liberalism than about any flaw in the ideal, and it would only justify *temporary* special measures for natives in order to raise them to an equitable level. Liberals have no objection to such "affirmative action" programs — indeed they were a part of the 1969 policy which attempted to remove all permanent constitutional differentiation between natives and other Canadians.

What can justify a special constitutional status for natives that goes beyond equal rights and resources? Let's instead ask why an egalitarian scheme of rights and resources is so important to the liberal. Such a scheme is important because it teaches each individual to make his or her decisions about how to lead their life with a view to the costs it has for others (Dworkin 1983, 31–32). Liberals believe that individuals should have to recognize and accept responsibility for the costs of the choices they make about how to lead their lives, and not ask or expect that others accept less in order that you can get more of what you want. As Dworkin says, "equality enters our plans by teaching us what is available to us, to deploy in accordance with our attachments and other concerns" (Dworkin 1983, 32).

This seems right — an egalitarian scheme of rights and resources is a fair way of dealing with the choices people make about leading their lives. But one thing it ignores is that inequality can arise *before* people make and act on decisions about how to lead their lives. Inequalities can arise over individuals' relationship to their *context of choice*, especially where the very existence of a cultural community is in danger of unwanted assimilation.

Some native leaders have sought to limit the voting rights of transient workers. If these non-natives were allowed to vote, they would probably decide to use public money to provide amenities for themselves — movie theatres, dish antennas for television reception, resort complexes etc. — at the expense of existing government programs to replenish the stock of wildlife the natives depend on, or to subsidize experimental hunting and ranching operations. Moreover, since many natives are dependent on short-term work projects during the break between hunting seasons, such a policy could force natives to move into localities dominated by whites, and to work and live in another culture, in a different language etc. To guard against this, native leaders have proposed a 3 to 10 year residency requirement before one becomes eligible to vote for or hold public office, and a guaranteed native representation in the regional government with veto power over legislation or land-uses that threaten native communities (Russell 1978; Asch 1984, Chap. 7).

If these political rights were viewed as assisting natives in pursuing their *choices* about their lives, then they would simply be unfair, since natives should have to bid alongside any others who wish to use the available resources. But that seems a misrepresentation of the effect of these rights. Rather than providing an advantage to natives over non-native bidders, they serve to correct an advantage non-natives have before the bidding starts. For the whites who wish to bid for northern resources, the security of *their* cultural community is not in question. They are bidding solely on the basis of what is useful in pursuing the goals they have chosen to pursue, secure in the knowledge that their context of choice is protected. For natives, on the other hand, they have to outbid the proposals of non-natives just to ensure their cultural structure survives, leaving them little, if anything, to pursue the particular goals they've chosen from within that structure. The point here is in fact the exact opposite of one of the anti-liberal arguments I discussed earlier. The point isn't that natives care more for their cultural structure than non-natives. We all care about the fate of our cultural community — the French-Canadians have always been extremely sensitive to anything that threatens their existence as a distinct community, and you all remember the paranoia in English-Canada when the bilingualism policy was first announced because people feared their culture was being submerged beneath that of French-Canada. The only difference is that non-natives rarely have to worry about the fate of

their cultural structure. They *would* pay to ensure the continued health of their culture, but there is no need for such payments. Non-natives get for free what natives have to pay for — i.e. security of their cultural structure. Special political rights serve to correct this inequality by ensuring that the native communities are as secure as non-native ones. People should have to pay for the costs of their *choices*, and equality of resources helps enforce that ideal, but special political rights are necessary to remove inequalities in the *context of choice*. This inequality would remain even if natives no longer suffered from any deprivation of material resources, and so temporary affirmative action programs are not enough to ensure genuine equality.

So far, I've argued two major points — firstly, that it is important, in deciding how to lead one's life, that one's cultural structure be both varied and secure. Individuals have to be able to lead their own lives, by their own lights — that is the liberal claim — and so the cultural (or political) structure can't be such as to, for example, deny individuals the right to choose their own religion, or sexual preference, or political party, or way of life in general. That is the heart of the liberal ideal, as expressed, for example, in Mill's claim that individuals ought to be free to do whatever they see as valuable, so long as it doesn't infringe on the legitimate rights or liberties of other individuals. Cultural structures should be a context in which individuals are free to make choices about how to lead their lives, not a particular way of life imposed on individuals, as it is in other political theories. It should just be a context of choice, but *every* individual should have their cultural context secured and respected. My second point is that to secure and respect the cultural communities in a plural society may require special economic and political measures that limit the mobility of non-members to outbid, or outvote, members of minority cultures — in other words, it requires legislation that assigns rights, opportunities and benefits on grounds of ethnicity. These two points, if true, mean that liberals are committed, by virtue of their own values, their own concern for individual choice and autonomy, to special measures that protect minority cultures.

Now that may strike you as paradoxical. For it is often said, by critics of liberalism, that what defines liberalism is its disregard for the context of choice, for the way individuals are embedded or situated in cultural communities:

> because liberalism disregards the social *system* as the basis of society, the liberal concept of individual choice is frequently a fallacy. It fails to detect that choices are possible only under certain social conditions.
>
> (Weaver 1981, 55)

Canadian philosopher Charles Taylor decries liberalism for its "atomism", for accepting an "utterly facile moral psychology" according to which individuals are self-sufficient outside of society, and hence not in need of any cultural context in order to make sense of their options, or exercise their capacity for choice (Taylor 1984, 197). Indeed, *advocates* of liberalism seem to say much the same thing — thus Rawls says that in a just society, people's self-respect is bound up entirely with their recognition as equal *citizens*, as if only membership in the *political* community matters, not membership in a cultural community (Rawls 1972, 544–545).

Canadian sociologist John Porter says "the saliency of ethnic differences is a retreat from the liberal notions of the unity of mankind [sic]" (Porter 1975, 303), which requires common *citizenship* for all members (Porter 1975, 297) — the "egalitarianism" he sees underlying liberalism requires treating individuals without regard to race or ethnicity. Speaking about Inuit claims for native rights, amongst other things, he considers group rights not only "regrettable" but "regressive" (Porter 1975, 298). Ponting and Gibbons are critical of liberalism for being "married" to this view of how individuals ought to be viewed by the law i.e. as incorporated into the constitution independently of any group membership (Ponting and Gibbons 1980, 330), but Bernard Schwartz considers it a virtue of liberalism that it refuses to see individuals as situated in any way in defined historical communities (Schwartz 1985). Liberals in the media, and even in opposition parties, viewed Trudeau's 1969 termination policy as a triumph of liberal equality, for it finally gave natives full recognition as equals, as fully equal in the eyes of the law and the constitution.

In the face of all this evidence, it would seem that any endorsement of collective rights can't be an improved spelling out of liberal values, as I've presented it, but rather a rejection of them. But it is important to note that all of these advocates *and* critics of liberalism are post-war writers. Perhaps these cliches about liberalism are better understood as a feature of the post-war intellectual climate generally, than as an intrinsic feature of liberalism. If we look at earlier liberals, especially the writings of Mill, Hobhouse, Green and Dewey, a different view emerges. They greatly emphasized both the importance of cultural heritage for individual autonomy, and the possibility that respecting cultural communities can require special political arrangements. They all stressed the importance of belonging to "communities" which have a consciousness of commonality deriving

> from a common dwelling-place with its associations, from common memories, traditions and customs, and from the common ways of feeling which a common language and still more a common literature embodies. (Green 1941, 130–131).

They praised "the sentiment of nationality" which Mill said was generated primarily by "the possession of a national history, and consequent community of recollections; collective pride and humiliation, pleasure and regret, connected with the same incidents in the past" (Mill, 360). Hobhouse felt that "pride and self-respect are closely bound up with it, and to destroy a nationality is in a degree to wound the pride and lower the manhood of those who adhere to it" (Hobhouse 1928, 146–147).

Gerald Gaus argues that the reconciliation of individuality and sociability was an important theme for these writers — in their works, liberalism was "transformed from a doctrine of competitive individualism to a cooperative pursuit of individuality" (Gaus 1983, 270). But he thinks that this desired reconciliation is jeopardized by their concern with the importance of communal identification. The pursuit of individuality, he argues, is incompatible with, "ultimately opposed" to, the unity which arises from "community" built on commonality and similarity (Gaus 1983, 108–109). But there needn't be any conflict here, for the *kind* of commonality involved — i.e. commonality of language and history,

shared membership in a cultural community — doesn't constrain individuality. On the contrary, membership in a cultural structure is what *enables* individual freedom, what enables meaningful choices about how to lead one's life. These liberals felt that individual liberty, the free and informed choice about how to lead one's life, was possible only in such a context of shared language and culture (Dewey 1928, 149; Mill 361; Hobhouse 1966, 41).

Because they recognized the importance of our cultural membership to individual liberty and social justice, they also recognized the importance of special measures for cultural minorities. Hobhouse, for example, believed that "the problem of dealing with the minority nation is the hardest that statesmen have to solve", (Hobhouse 1928, 146), and that "the more liberal statesmanship of modern times" has recognized the necessity of minority rights to ensure "cultural equality" (Hobhouse 1966, 297n, 299). Different measures would be needed in different situations, but "clearly it is not achieved by equality of franchise. The smaller nationality does not merely want equal rights with others. It stands out for a certain life of its own" (Hobhouse 1928, 146–147). But what was clear to Hobhouse and Mill, and to "the more liberal statesmanship" of their day — i.e. that people are owed respect both as political citizens and as cultural members, and so "equality of franchise" may have to be qualified where cultural minorities exist — has become very obscure to the more liberal statesmen and theorists of our day. An important question of justice and respect has simply been lost to the liberal agenda.

Post war liberals say that their ideal is characterized by "the prohibition of any legal or governmental recognition" of cultural or linguistic groups "as corporate entities with a standing in the legal or governmental process" (Gordon 1975, 105), and that group specific rights are only appropriate if

> the task of a just society is to make representation [of groups] equal, even if this means the individual is not treated as an individual, but must be considered as a member of the group.
>
> (Glazer 1978, 97)

Set up this way it's not surprising that the liberal concern is with treating individuals as individuals and as equals, without regard to any group membership, rather than treating groups as equals. But these post-war liberal cliches need to be rethought, for they misrepresent the issue, as well as misrepresenting their own tradition. A government that gives native individuals special rights as members of a distinct cultural community may still be treating them as individuals — the provision of such rights just reflects a different view about *how* to treat them as individuals and as equals. As Glazer correctly notes, the post war liberal choice presupposes that we should accept a "model" in which "group membership is purely private, a shifting matter of personal choice and degree" (Glazer 1978, 98–99). But this isn't a decision to treat individuals, rather than groups, as equals — it's a decision to treat individuals as having a certain relationship to their cultural community, namely a relationship such that belonging to it is like belonging to a local club — i.e. a purely private matter of "personal choice". But that isn't the only way to treat individuals, and indeed it's a false view, as earlier liberals recognized. Since it is a false view, it fails to treat individuals as equals, for it means that native individuals will face an inequality not due to purely private personal choice. If we decide that the inequality should be corrected, through the collective measures discussed above, we do so because that is what's needed to treat *individuals* as equals. Neither view is more concerned with treating individuals as equals than the other — they just reflect different views of what individuals are, and hence what it is to treat them as equals.

Liberalism is indeed about equality for individuals, but what it means to treat individuals as equals depends on what it is in virtue of that they are owed respect and concern. I believe it is in virtue of their citizenship in political communities *and* their membership in cultural communities — for it is in and through the political structure that individuals are ensured of their ability to execute their chosen life plans, and it is in and through the cultural structure that they come to an awareness of the meaning and range of the options available to them. These are jointly necessary for the fullest exercise of one's moral powers and one's autonomy, the possession of which is what makes individuals subjects, and equal subjects, of a theory of justice.

Minority rights, therefore, have been, and should continue to be, an important part of liberal political practice. But they present a serious *political* challenge, for they call into question one of the fundamental parts of the liberal political tradition — i.e. a Bill of Rights. Both French-Canadians and native Canadians are seeking exemption from the equal rights provision of the new Charter. If the defense of liberal politics depends on having a respected constitution, then it becomes a pressing concern to find an interpretation of the equality provisions of the Charter that allows for legitimate measures of cultural protection without depriving either native or non-native individuals of an ability to claim their equal status in the courts.

References

Asch, M. 1984. Home and Native Land: Aboriginal Rights and the Canadian Constitution. Toronto: Methuen.

Berger, T. 1977. Northern Frontier, Northern Homeland: The Report of the Mackenzie Valley Pipeline Inquiry. Ottawa: Supply and Services Canada.

Cardinal, H. 1969. The Unjust Society: The Tragedy of Canada's Indians. Edmonton: Hurtig Publishers.

Crowe, K. 1974. A History of the Original Peoples of Northern Canada. Montreal: McGill-Queen's University Press.

Dacks, G. 1981. A Choice of Futures: Politics in the Canadian North. Toronto: Methuen.

Dene Nation. 1976. "Agreement in principle". In: Watkins, M. ed. Dene Nation: The Colony Within. Toronto: U. of Toronto Press.

Department of Indian and Northern Affairs. 1969. "Indian policy". In Bowles, R. and Hanley, J. eds. The Indian: Assimilation, Integration or Separation. Scarborough: Prentice-Hall.

Dewey, J. 1928. The Public and its Problems. London: Allen and Unwin Ltd.

Dworkin, R. 1983. "In defense of equality". Social Philosophy and Policy. Vol. 1, No. 1.

Ewers, J. 1981. "Inter-tribal warfare as the precursor of Indian-White warfare in the northern great plains". In: Nicols, R., ed. The American Indian: Past and Present. New York: John Wiley and Sons.

Fishman, J. 1972. The Sociology Of Language. Rowley: Newbury House.

Gaus, G. 1983. The Modern Liberal Theory of Man. London: Croom Helm.

Glazer, N. 1978. "Individual rights against group rights". In: Kamenka, E. and Tay, A. eds. Human Rights. London: Edward Arnold Ltd.

Gordon, M. 1975. "Toward a general theory of racial and ethnic group relations". In: Glazer, N. and Moynihan, D. eds. Ethnicity: Theory and Experience. Cambridge: Harvard U. Press.

Green, T. 1941. Lectures on the Principles of Political Obligation. London: Longmans, Green and Co.

Gross, M. 1973. "Indian control for quality Indian education". North Dakota Law Review. Vol. 49.

Haimila, W. 1978. "Directions and tendencies of the Council of the Northwest Territories with respect to Native claims". In: Keith, R. and Wright J. eds. Northern Transitions. Volume 2. Ottawa: Canadian Arctic Resources Committee.

Hobhouse, L. 1928. Social Evolution and Political Theory. New York: Columbia U. Press.

_____ 1966. Social Development: Its Nature and Conditions. London: Allen and Unwin.

International Herald Tribune. 1985. "Botha rejects plea from within party to end home school segregation". October 3. p. 2.

Macintyre, A. 1981. After Virtue. London: Duckworth.

Mkhwanazi, F. 1985. "Apartheid's long winter sunset". National Student. Vol. 82.

Ponting, R. and Gibbons, R. 1980. Out of Irrelevance: A Socio-political Introduction to Indian Affairs in Canada. Toronto: Butterworth.

Porter, J. 1975. "Ethnic pluralism in Canadian perspective". In: Glazer, N. and Moynihan, D. eds. Ethnicity: Theory and Experience. Cambridge: Harvard U. Press.

Rawls, J. 1972. A Theory of Justice. London: Oxford U. Press.

Russell, P. 1978. "An analysis of the land claims position of the Metis Association of the Northwest Territories". In: Keith, R. and Wright, J. eds. Northern Transitions. Volume 2.

Schwartz, B. 1985. First Principles, Second Thoughts: Constitutional Reform with Respect to the Aboriginal Peoples of Canada. Kingston: Institute of Intergovernmental Relations.

Seltzer, A. 1980. "Acculturation and mental disorder in the Inuit". Canadian Journal of Psychiatry. Volume 25.

Sparham, R. 1978. "Political development in the northwest territories". In: Keith, R. and Wright, J. eds. Northern Transitions. Volume 2.

Taylor, C. 1984. Philosophy and the Human Sciences: Philosophical Papers. Volume 2. Cambridge: Cambridge U. Press.

Toronto Star. 1986. "Botha's Warning". Sept. 28. p. B3.

Weaver, S. 1981. Making Canadian Indian Policy. Toronto: U. of Toronto Press.

Wuttunee, W. 1971. Ruffled Feathers: Indians in Canadian Society. Calgary: Bell Books.

HISTOIRE DE L'UTILISATION DES RESSOURCES NATURELLES PAR LES INUIT DANS LES ESTUAIRES DE KANGIQSUJUAQ: PERSPECTIVE ETHNOARCHÉOLOGIQUE

Yves Labrèche

Département d'anthropologie, Université de Montréal, Montreal, Quebec H3C 3J7
et chercheur au Laboratoire d'archéologie à l'Université du Québec à Montréal, Montréal, Québec H3C 3P8

Niveau: Doctorat

Résumé

L'auteur a effectué une reconnaissance archéologique au cours de l'été 1985 en collaboration avec deux Inuit dans la région de Kangiqsujuaq (Wakeham Bay) au Québec arctique. Deux zones estuariennes ont été explorées, et 25 sites, dont la majorité semblent historiques ou modernes, ont été découverts et répertoriés. Des camps de pêche, incluant entre autres des emplacements de tentes et des caches ainsi qu'un affleurement de stéatite exploité autrefois et aujourd'hui, ont fait l'objet d'une attention particulière.

Je présente ici les résultats préliminaires de cette recherche qui se poursuit en 1986. L'interprétation des données recueillies tient compte des témoignages des Inuit sur l'histoire de l'utilisation qu'eux et leurs ancêtres faisaient des lieux d'établissement, du poisson, du caribou ainsi que des roches ou minéraux comme la stéatite. Pour l'instant, l'étude du mode de subsistance montre que les Inuit fréquentaient les estuaires principalement pour la pêche d'été, au moment où l'omble chevalier s'y trouve en grand nombre. Il arrivait que les Inuit prenaient aussi quelques caribous, car au cours de cette même saison, ces grands mammifères terrestres venaient parfois se réfugier sur la côte. Les estuaires permettent donc le développement de stratégies d'acquisition et d'utilisation de ressources qui constituent une alternative ou un complément par rapport aux mammifères marins.

Mots-clés: Arctique, Inuit, ethnoarchéologie, estuaires, ressources minérales, poisson, caribou.

Abstract

The author conducted an archaeological survey during the summer of 1985 in collaboration with two Inuit in the region of Kangiqsujuaq (Wakeham Bay) Arctic Quebec. Two estuarian zones were explored, and 25 historic and contemporary sites were found and recorded. We focused our attention on such sites as fishing camps including tent rings and caches, and a soapstone outcrop which was traditionally used by the Inuit.

In this paper, I present the preliminary results of this research which was pursued in 1986. The interpretation of collected data includes Inuit opinions concerning past utilisation of camps, fish, caribou and rocks and minerals such as soapstone. The results of subsistence study shows that the Inuit were frequenting the estuarian zones mainly for arctic char fishing during summer time. But the Inuit also killed caribous, because these land mammals come to the coast at that time of the year. Therefore, estuarian subsistence strategies represent an alternative or a complementary activity to sea mammal hunting.

Key words: Arctic, Inuit, ethnoarchaeology, estuaries, mineral resources, fish, caribou.

Introduction

Au cours de l'été 1985, j'ai entrepris en collaboration avec deux Inuit de Kangiqsujuaq, une reconnaissance archéologique d'une durée de quatre semaines au Québec arctique. Plus précisément, nous avons effectué des relevés dans deux

zones estuariennes donnant sur le détroit d'Hudson. Les données récoltées concernent surtout l'histoire de l'occupation inuit de cette région, et l'utilisation qu'ils faisaient et font encore aujourd'hui de certaines ressources qui s'y trouvent.

J'ai préparé cette communication à Kangiqsujuaq, en septembre 1986, au moment où j'entreprenais une seconde période de relevés archéologiques dans les deux mêmes zones qui se trouvent à quelques kilomètres de ce village. Les interprétations que je présente sont donc préliminaires puisque les informations obtenues en 1986 n'ont pas encore fait l'objet d'une analyse approfondie. Cette année, j'ai consacré une attention particulière aux vestiges comme les caches de pierre qui témoignent des pratiques traditionnelles de conservation ou de mise en réserve de la viande et du poisson.

Ces activités sur le terrain font partie d'une démarche plus globale que j'ai entreprise et qui consiste à analyser des données sur deux aspects particuliers de l'histoire des stratégies de subsistance dans le Nord: 1- les modes de récolte alternatifs et complémentaires par rapport à la chasse aux mammifères marins; 2- les techniques de conservation alimentaire. Ces problèmes n'ont jamais vraiment fait l'objet d'études approfondies par les archéologues qui s'intéressent à l'Arctique, peut-être parce qu'ils sont peu «visibles» d'un point de vue archéologique, mais peut-être aussi, comme l'a déjà souligné Balikci (1980:7), parce que la pêche ou la préparation de réserves alimentaires n'ont pas le côté spectaculaire des grandes chasses au caribou d'automne; elles ne sont pas non plus des activités prestigieuses car elles ne présentent pas autant de risque immédiat que la chasse aux grands mammifères marins.

Les gens de Kangiqsujuaq et leur environnement

La communauté de Kangiqsujuaq comprend aujourd'hui environ 300 Inuit qui vivent en grande partie des produits de leur chasse et pêche. Les Inuit chassent surtout les mammifères marins et principalement le phoque et la baleine blanche. Mais particulièrement en été et jusqu'au début de l'automne, ils pêchent l'omble chevalier. On sait en effet que cette espèce anadrome est disponible sur toute la bande côtière à ce moment de l'année, et les estuaires deviennent alors des lieux de pêche privilégiés. À l'occasion, les Inuit y font aussi la chasse au caribou, et en septembre, la récolte de petits fruits sauvages comme la camarine noire et le «bleuet» qui s'y trouvent en abondance.

Le territoire des gens de Kangiqsujuaq s'étend vers l'intérieur des terres, en direction du sud-ouest, depuis la côte du détroit d'Hudson. Il couvre une superficie de 5788,6 km^2 selon les termes de la Convention de la baie James et du Nord québécois; mais évidemment, l'espace parcouru par les Inuit de cette localité ont toujours dépassé largement le cadre juridique étroit imposé par cette convention. Nos deux zones d'exploration sont situées sur la côte, dans la partie nord-est de ce territoire, entre 9,5 et 20 km du village. Celui-ci est établi dans la baie de Wakeham qui s'ouvre sur le détroit d'Hudson, au nord du 61^e parallèle, et à quelque 90 km à l'ouest de l'entrée de la baie d'Ungava.

Le relief est très prononcé dans cette partie de la côte sud du détroit, et les rivières ne sont pas navigables, en raison de leur faible débit. Mais nous savons qu'il s'agit d'un milieu depuis longtemps propice à l'implantation des populations humaines, car plusieurs sites dorsétiens et thuléens reliés surtout au contexte maritime ont été répertoriés il y a quelques années (voir Barré 1970).

Le climat est très rigoureux, la température moyenne du mois le plus chaud, soit juillet étant de 5.7 degrés C, et celle du mois le plus froid, soit février étant de −27 degrés C (Environnement Canada, 1975). La toundra comprend principalement des plantes, mousses et lichens, et dans une moindre mesure, des arbustes qui sont rampants, sauf dans les lieux abrités des vents dominants et bien exposés aux rayons du soleil où ils sont dressés et plus nombreux.

Les rivières sont encaissées, jalonnées de rapides, et leur bassin versant est d'importance secondaire, du moins par comparaison avec celui d'autres rivières comme l'Arnaud (baie d'Ungava) et la Povungnituk (baie d'Hudson). L'apport en éléments nutritifs des rivières étant généralement élevé, aussi, dans les eaux estuariennes, les ressources fauniques utiles aux communautés humaines sont particulièrement concentrées. Par contre, la diversité des espèces est limitée par la grande variabilité des conditions. Ainsi, les espèces présentes doivent notamment être tolérantes à un changement extrême de la salinité comme par exemple l'omble chevalier (Dyer, 1973: v, 1-3). Or rappelons que cette espèce n'est présente que quelques mois par année, et remonte vers les lacs de l'intérieur en septembre.

Enfin, mentionnons que la zone à l'embouchure de la rivière Wakeham n'est vraiment navigable qu'à marée haute, bien sûr après la débâcle qui a lieu vers la fin juin, et jusqu'au moment de l'englacement (novembre). Mais déjà en septembre, les vents persistants rendent les conditions de navigation très hasardeuses.

Les sites fréquentés par les Inuit et leurs prédécesseurs

Découvertes et relevés sur le terrain

En 1985, le projet comportait une dimension ethnographique et s'est fait en collaboration avec deux informateurs inuit qui ont fourni à plusieurs reprises une interprétation ou des renseignements complémentaires concernant les vestiges archéologiques que nous avons observés. Vingt-cinq sites dont la majorité semblent historiques ou modernes ont été découverts et répertoriés. Il s'agit de camps de pêche ou de chasse incluant des emplacements de tentes, des foyers extérieurs caractéristiques de la saison estivale, ainsi que des caches ayant servi à l'entreposage de la nourriture. Nous avons également observé une maison semi-souterraine, des abris appuyés sur affleurement rocheux, un affût pour guetter le caribou, des pièges à renard, ainsi qu'un lieu où se fit le recouvrement de carcasses de kayaks. Enfin, nous avons effectué des relevés sur un affleurement de stéatite parmi la roche formant le flanc haut d'une colline.

En 1986, j'ai travaillé avec deux jeunes assistants inuit, et cette fois, la recherche a pris une orientation nettement archéologique. Nous sommes retournés dans les deux zones explorées en 1985 pour: 1- effectuer la cartographie à grande échelle et faire des observations complémentaires sur six sites enregistrés l'an passé; 2- poursuivre l'exploration d'une partie des zones qui n'avait pas été complétée en 1985. Nous

avons ainsi localisé trente autres stations distribuées sur environ 6 km le long de la côte et comprenant une ou plusieurs structures: habitations, caches etc. L'identification très sommaire faite au moment où nous avons parcouru pour la première fois cette nouvelle partie du terrain a servi ensuite à sélectionner, en tenant compte évidemment de la problématique, huit stations où des relevés plus complets ont été effectués.

Interprétations préliminaires

J'ai choisi de résumer ici quelques données significatives concernant la nature, l'envergure, la densité, la saison et la séquence de l'occupation inuit des deux zones, en insistant sur l'utilisation immédiate ou différée des ressources naturelles.

Traditionnellement, les tentes étaient utilisées surtout au cours de l'été et de l'automne. Or la majorité des vestiges d'habitations répertoriés en 1985 et en 1986 correspondent effectivement à des emplacements de tentes. Seulement trois sites comprennent des indices qui suggèrent une occupation des estuaires en saison froide. L'un (JjFb-18) comprend une maison semi-souterraine, et aux deux autres (JjEx-4 et JjFb-19) se trouvent respectivement un et deux emplacements d'igloos.

La répartition géographique des habitations dans les estuaires est très variable, allant des abris ou des tentes isolés jusqu'aux sites préférés des Inuit qui comprennent une dizaine d'habitations ou plus. Ces sites dont la superficie et la complexité sont plus grandes comprennent généralement des caches et parfois d'autres structures secondaires moins nombreuses.

Considérons donc plus en détail la distribution spatiale et saisonnière des vestiges dans la zone estuarienne de la rivière Wakeham pour laquelle l'analyse des données est actuellement plus avancée.

La majorité des restes fauniques identifiés comme mammifères marins proviennent d'un site (JjFb-18) de la rive droite. À cet endroit se trouvent aussi la seule maison semi-souterraine, et non loin, en amont de ce lieu, l'emplacement de deux igloos (site JjFb-19). Signalons également que l'affleurement de stéatite perché sur le flanc d'une colline (site JjFb-10) se trouve sur cette même rive de l'estuaire. Deux blocs de cette matière qui est souvent exploitée en hiver ont été trouvés associés, l'un à la maison semi-souterraine et l'autre à une cache située à quelque cinquante mètres de cette habitation. Le transport de la stéatite se faisait probablement plus facilement par traîneau, et donc, lorsque les conditions de neige et de glace le permettaient. Les indices trouvés sur ces trois sites illustrent donc des activités référant à la saison froide et se trouvent distinctement groupés sur la rive droite.

Sur un site de la rive gauche (JjFb-3), nous avons identifié des os longs de caribou qui avaient été fracturés pour l'extraction de la moelle. Ceux-ci étaient associés à un emplacement de tente. Bien que des os ou de l'andouiller de caribou aient été trouvés à trois endroits situés plus près de la mer et sur l'une ou l'autre rive, c'est surtout à partir de ce lieu (nous sommes ici à 3,5 km de la limite estuaire/mer) et en amont de celui-ci, toujours en longeant la rive gauche, que la majorité des traces de caribou ont été observées et que quatre caribous ont été tués par les chasseurs inuit au cours de notre premier séjour, en juillet 1985.

Au moins deux sites sont des camps de pêche (JjFb-1 et JjFb-2) qui ont été occupés au cours de l'été. D'après le témoignage des Inuit, c'est également au cours de l'été que se faisait le recouvrement des carcasses de kayaks, activité représentée à l'un de ces sites (JjFb-1). À cette fin, mes informateurs croient qu'on utilisait de préférence la peau de caribou qui est plus légère quoique peut-être moins imperméable et résistante que les peaux de mammifères marins. J'aimerais cependant mentionner que sauf chez les Inuit du Caribou (Arima, 1975:104), les kayaks étaient généralement couverts de peaux de mammifères marins (Boas, 1975:9–12). Enfin, parce que les tentes sont souvent transportées et installées de façon temporaire, celles-ci devaient également être couvertes de peaux de caribou, du moins lorsque cette espèce était présente en abondance dans la région.

Les lieux préférés actuellement pour la pêche au filet semblent concentrés dans une section précise de la rive gauche (de JjFb-1 à JjFb-11) qui se trouve autour de 2,5 km de la limite estuaire/mer. Cependant, les caches à poisson découvertes sur deux autres sites (JjFb-5 et JjFb-7) montrent que l'omble chevalier peut parfois être pris en quantité encore plus en amont et entreposé sur l'une ou l'autre rive. J'ouvre ici une petite parenthèse: d'après mes informateurs inuit, les pierres utilisées dans la construction des caches pour l'entreposage du poisson sont généralement de petite dimension. J'ai aussi remarqué que les caches pour la viande comprennent souvent des blocs érigés ou superposés alors que les caches pour le poisson ressemblent davantage à un amoncellement de galets formant un monticule peu prononcé sous lequel le sol peut parfois avoir été creusé. Par contre les Inuit d'aujourd'hui ne semblent pas distinguer des types de caches, du moins lorsqu'il est question d'entreposer du phoque ou du caribou.

Pour la datation relative des sites, nous retiendrons les critères suivants: l'altitude du site et la distance de la rive, le type de structure, les vestiges diagnostiques associés et les témoignages des informateurs inuit. Le poids que nous accordons à chacun de ces critères varie cependant suivant la nature du site. Ainsi, il est clair qu'en plus de la présence des ressources convoitées, la proximité de la rive ou d'une source d'eau potable sont des facteurs qui peuvent avoir influencé le choix de l'emplacement des campements par les Inuit. Par contre, des critères combinés de façon différente intervenaient lorsqu'il était question de construire un piège, une cache pour l'entreposage ou une sépulture. Ainsi, par exemple, en Ungava et au Labrador, les sépultures étaient souvent installées sur les hauteurs et/ou comme en retrait des habitations ou des lieux plus passants. Deux cas observés en 1985 et 1986 nous ont permis de constater à nouveau la validité de cette règle générale.

Parmi l'ensemble des tentes examinées en 1985, il est possible de distinguer les tentes ovales ou rondes modernes des tentes plus anciennes qui comportent parfois un dallage dans la moitié arrière correspondant à l'aire de couchage. D'après Vézinet (1982:21), l'usage des tentes modernes faites de canevas ne s'est généralisé qu'après 1920. Or d'après nos données, les tentes qui sont appuyées sur un bloc en place ou un affleurement rocheux datent de la période des couvertures de peaux, et donc d'avant cette date. Parmi les cinq structures de ce type répertoriées en 1985, deux se trouvent perchées sur les hauteurs d'une colline, entre 14 et 23 mètres

d'altitude au-dessus du niveau marin actuel. L'altitude suggère donc aussi que ces structures sont relativement anciennes car compte tenu du relèvement isostatique, les sites les plus près du niveau marin actuel sont nécessairement récents. Les tentes étaient autrefois installées sur les hauteurs afin de mieux voir venir le caribou; l'altitude pourrait donc refléter ici aussi une stratégie adaptative, d'autant plus qu'un fragment d'andouiller a effectivement été découvert enfoui dans le sol à l'intérieur d'une des deux tentes.

Aucun des sites enregistrés au cours de 1985 et 1986 n'est clairement préhistorique. Pourtant, des sites préhistoriques découverts à proximité de barrages pour la pêche ou près de l'embouchure de rivières ont été découverts ailleurs dans l'Arctique (Maxwell, 1985:89; Mary-Rousselière, 1968:7). Or l'orientation ethnoarchéologique donnée à la première phase de notre recherche ne permet pas d'expliquer à elle seule pourquoi la fréquentation des estuaires semble être ici un phénomène historique ou moderne. En effet, cette année nous avons pratiqué de nombreux sondages au sol, à l'intérieur et autour de nombreuses structures qui ont livré des os, donc des renseignements sur la faune, mais très peu d'indices reliés au travail de la pierre. Ainsi, exceptionnellement, quatre éclats de quartz ont été observés à l'intérieur d'une tente (site JjEx-2) qui se trouve à moins de 3,00 mètres d'altitude. De même, quelques traces ponctuelles d'exploitation de la stéatite ont été observées sur l'emplacement même de l'affleurement, et bien que la solidification de la pierre, autour de ces traces indique une certaine ancienneté (interprétation fournie par mes informateurs), il est actuellement impossible d'affirmer qu'il s'agit d'une activité préhistorique.

Le fait que la maison semi-souterraine (JjFb-18) mentionnée précédemment se trouve à moins de 1,60 mètre d'altitude suggère que cette structure n'est pas très ancienne. Aujourd'hui les Inuit de Kangiqsujuaq même s'ils savent évidemment que leurs ancêtres vécurent dans ces habitations, ne se souviennent cependant pas en avoir eux-mêmes habité. La maison semi-souterraine date donc au moins de la fin du siècle dernier.

Parmi les sites répertoriés en 1985, quatre comprennent des habitations dont l'altitude dépasse 3,00 mètres, et de ce nombre, trois (JjFb-11, -14 et -21) pourraient correspondre à des occupations préhistoriques. L'autre site (JjFb-2) comprend cependant des tentes qui ont été identifiées comme modernes par le témoignage d'un informateur inuit et l'observation sur place de vestiges récents. L'âge de trois autres sites modernes a été précisé par mes informateurs, comme par exemple l'emplacement de deux igloos érigés il y a environ quarante ans.

Retenons ici en camp de pêche (JjFb-1) fréquenté par les Inuit et dont la datation permet de replacer un aspect de l'histoire locale dans la séquence globale des changements techniques récents auxquels ont eu à faire face les peuples de l'Arctique. Ce campement comprend une structure de recouvrement de kayaks qui date d'au moins vingt-cinq ans puisque les Inuit n'en fabriquent plus depuis 1960. La structure allongée mesure 9,80 par 2,40 mètres et les dalles périphériques disposées autour de la carcasse de l'embarcation auraient servi pour étendre les peaux. Selon mes informateurs, le travail se faisait en été: les hommes étiraient et mordaient les peaux et les femmes cousaient. Dix femmes et cinq hommes pouvaient collaborer ainsi pendant cinq jours et une personne cuisinait continuellement sur un foyer situé à proximité et du côté arrière de l'aire d'activité principale. Si ces chiffres sont exacts, alors ce travail collectif portait sur la confection de plusieurs embarcations.

Pour ce qui a trait à la durée des séjours, la plupart des données indiquent que les gens se sont installés durant de courtes périodes. De façon ponctuelle, nous avons appris, entre autres, que pour un séjour d'un mois à un camp de pêche (site JjFb-2) il y a 50 ans, une famille inuit avait apporté des provisions incluant de la viande de phoque. A cette époque, il n'y avait pas de caribou dans la région depuis plusieurs années. De façon plus générale, j'ai déjà souligné le fait que la présence de l'omble chevalier est très saisonnière; or celui-ci est la principale ressource alimentaire disponible dans les estuaires en été, saison des déplacements, c'est-à-dire lorsque les Inuit vivent davantage sous la tente.

Conclusion

Les données récoltées en 1985 et 1986 sont à la fois considérables et fragmentaires. Aussi, d'autres travaux incluant des vérifications sur le terrain sont prévus pour 1987. Pour l'instant, l'étude préliminaire de la distribution spatiale et temporelle des restes matériels enregistrés dans l'estuaire de la rivière Wakeham montre que: 1- la fréquentation des estuaires est un comportement principalement historique et moderne chez les Inuit de Kangiqsujuaq; 2- la pêche d'été est l'activité principale dans cette zone, et les grandes pêches se font en certains lieux privilégiés à l'intérieur de celle-ci; 3- la chasse au caribou se fait également en certains lieux privilégiés; 4- il y a une certaine séparation entre habitats d'hiver et habitats d'été.

Jusqu'ici, les études archéologiques avaient porté davantage sur le mode d'adaptation maritime des peuples du Québec arctique; en ce sens, l'analyse des nouvelles données recueillies permettra de répondre à des questions précises concernant les stratégies de subsistance alternatives ou complémentaires. Nous l'avons vu, l'une de ces questions concerne la constitution de réserves alimentaires. Une étude approfondie sera consacrée à cette question et comprendra idéalement plusieurs volets ou étapes: identification et datation des os, caractérisation physio-chimique des sols, calibrage lichénométrique, fouille minutieuse des documents ethnographiques et ethnohistoriques concernant l'économie traditionnelle des Inuit, et enfin, comparaison trans-culturelle des techniques de mise en réserve considérées comme chaînon important dans la production alimentaire.

Remerciements

Je tiens à remercier tous les gens de Kangiqsujuaq pour leur accueil très chaleureux et à mentionner à quel point j'ai apprécié les échanges que nous avons eus lors de mes deux séjours sur leur territoire. Je remercie également MM. Asen Balikci, Norman Clermont, Patrick Plumet et Serge Lebel qui ont accepté de lire et commenter la version préliminaire de cette communication. Le Ministère des affaires culturelles du Québec a permis la réalisation des travaux sur le terrain en accordant les subventions nécessaires au Laboratoire d'archéologie de l'UQAM dirigé par M. Patrick Plumet. De plus, dans le cadre de son Programme d'aide à la formation scientifique dans le Nord, le Ministère des affaires indiennes et du Nord (Ottawa) a défrayé les coûts liés au transport et à la subsistance en 1985 ainsi qu'en 1986.

Références

Arima, E.Y. 1975. A contextual study of the Caribou Eskimo kayak. Le Service canadien d'ethnologie, Collection Mercure no. 25, Musée national de l'Homme, Ottawa.

Balikci, A. 1980. Charr fishing among the Arvilijuarmiut, in E.K. Balon éd. Charrs: salmonid fishes of the genus Salvelinus. Dr. W. Junk bv Publications, The Hague: 7-9.

Barre, G. 1970. Reconnaissance archéologique dans la région de la baie de Wakeham (Nouveau-Québec). S.A.P.Q., Ateliers Jacques Gaudet (Distribution: Recherches amérindiennes au Québec).

Boas, F. 1975. The Eskimo of Baffin land and Hudson Bay. I-II (1901-1907), AMS press, N.Y.

Dyer, K.R. 1973. Estuaries: A Physical Introduction. John Wiley and Sons, London.

Environnement Canada 1975. Normales au Canada: températures 1941-70. Tome 1—51. Environnement atmosphérique, Downsview, Ontario.

Labreche, Y. 1986. Ethnoarchéologie dans la région de Kangiqsujuaq au Québec arctique en 1985. Ms., Laboratoire d'archéologie, U.Q.A.M., Montréal.

Mary-Rousseliere, G. 1968. Reconnaissance archéologique dans la région de Pond-Inlet, Territoires du Nord-ouest. C.E.N., Collection Travaux divers no. 21, Université Laval, Québec.

Maxwell, M.S. 1985. Prehistory of the Eastern Arctic. Academic Press, Orlando.

Vezinet, M. 1982. Occupation humaine de l'Ungava: perspective ethno-historique et écologique. Collection Paléo-Québec no. 14, Laboratoire d'archéologie, U.Q.A.M., Montréal.

Illustrations

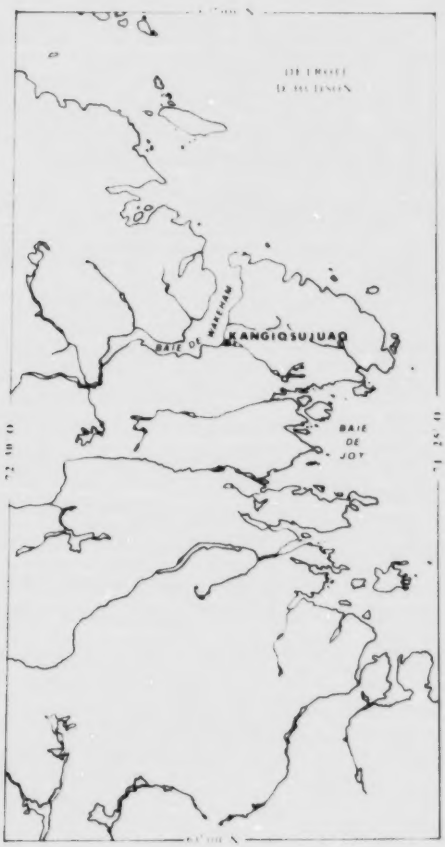


Figure 1. Carte de localisation des deux zones d'intervention archéologique en 1985 et 1986 dans la région de Kangiqsujuaq au Québec arctique.

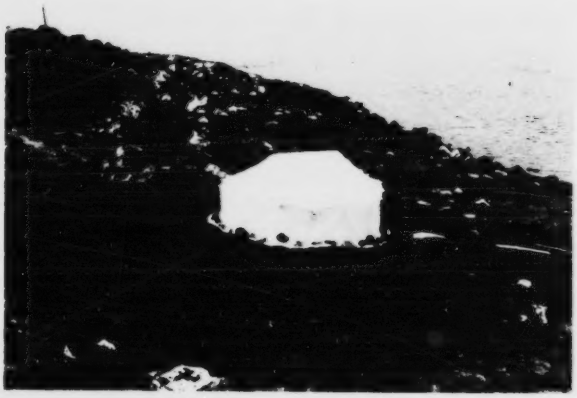


Photo 1. Vue d'ensemble d'un site (JjFb-16) sur la rive droite de l'estuaire de la rivière Wakeham où nous avons installé notre camp en 1986.

Photo 2. Les Inuit entreposaient la viande dans des caches de pierres.

Photo 3. Les deux jeunes assistants inuit commencent les sondages au site JjFb-7, interprété provisoirement comme lieu de pêche.

AN EXERCISE IN SOVEREIGNTY: THE CANADIAN GOVERNMENT AND THE RELOCATION OF INUIT TO THE HIGH ARCTIC IN 1953

Keith Lowther

Department of History, Trent University, Peterborough, Ontario K9J 7B8

Level: Bachelor's

Abstract

Due to a perceived lack of wildlife on which to sustain its Inuit population, the Canadian government commenced the transfer of several Inuit families from the Port Harrison, Quebec and Pond Inlet, Baffin Island regions to two remote locations in the Arctic Archipelago in 1953. Although viewed at the time simply as an attempt to aid the Inuit people of the Port Harrison region, the government's plan was based on contradictory information found in several reports of the Eastern Arctic Patrol. Rather than humanitarian motives, political considerations were ultimately the deciding factor in the decision to begin the relocation. Fear of an American presence in the Arctic due to the recently constructed weather stations and coming radar installations and the possible threat to Canadian sovereignty, which came with such joint projects, convinced the government that it was necessary that the region have permanent communities of Canadian citizens. The Inuit were the natural choice for settling these remote locations.

Key words: Relocation, Inuit, Port Harrison, Quebec, Pond Inlet, N.W.T., Ellesmere Island, Resolute Bay, sovereignty.

Résumé

Se fondant sur l'absence apparente de faune permettant d'alimenter la population inuit de Port Harrison, Québec, le gouvernement du Canada avait mis en oeuvre, en 1953, un plan de transfert de plusieurs familles de cette région, ainsi que d'autres de l'île de Baffin, vers deux localités éloignées de l'archipel arctique. Bien qu'à ce moment-là le plan apparût comme une tentative d'aider les Inuit de la région de Port Harrison, il était basé sur des informations contradictoires tirées de plusieurs rapports de la Patrouille de l'Arctique oriental. Plutôt que les motifs humanitaires, ce furent des considérations politiques qui finalement firent pencher la balance en faveur d'un transfert de la population. Les craintes suscitées par la présence des Américains dans l'Arctique, suite à l'achèvement récent des stations de radar, et qui pourraient en découler pour la souveraineté canadienne sur ces territoires, avaient convaincu le gouvernement de la nécessité d'y installer des collectivités permanentes de citoyens canadiens. Les Inuit constituaient le choix naturel pour faire acte de présence dans ces territoires périphériques.

Mots-clés: Transfert de population, Inuit, Port Harrison, Québec, Pond Inlet, T.N.-O., île d'Ellesmere, Resolute Bay, souveraineté.

Introduction

The Canadian government's concern for the Arctic region and its native inhabitants has always been of a questionable nature. Were policies, initiated ostensibly for the benefit of the indigenous peoples of the area, the result of a deeply felt sense of concern for their welfare, or were powerful forces, having little to do with them, forcing the government to act? During the course of this paper I will prove that in at least one instance this latter theory was the case.

Beginning in early 1952 a plan to relocate small groups of Inuit to the Arctic Archipelago was being discussed by the Northwest Territories Council, the Royal Canadian Mounted Police and representatives of the Department of Resources and Development. As proposed in a letter to RCMP Commissioner L.H. Nicholson by "G" Division's Commanding Officer, H.A. Larson, a relocation to Ellesmere Island was first seen as a way to improve the economic circumstances of several families from the Pond Inlet area (Hammond, 1984: 3). However by the end of the year, the scope of the plan was enlarged so that five Inuit families would be moved to Craig Harbour and Bache Peninsula on Ellesmere Island and ten to Resolute Bay, Cornwallis Island. The participants would be volunteers from the established communities of Port Harrison, Quebec and Pond Inlet and Cape Dorset, Baffin Island. Port Harrison and Cape Dorset natives were targetted for relocation because federal officials felt that the increasing native populations of the two regions placed too large a demand on the land for the continuation of a traditional subsistence economy. By moving a portion of the population to areas farther north, where there were deemed to be sufficient wildlife resources, it was hoped that the original and newly founded communities would prosper. Inhabitants of Pond Inlet were included in the project to aid the people from the more southern settlements to adapt to the unaccustomed conditions in the High Arctic.

This policy of relocation was only one part of a larger plan which the Department of Resources and Development had established for the welfare of the Inuit. In southern regions, Inuit living near white settlements were to be assimilated through education. Farther north, they were encouraged to continue their traditional lifestyle providing that there were sufficient natural resources. If this last requirement was not met then relocation to more suitable districts was advised.

In April 1953, the relocation scheme was again altered so that only fifteen families would move to the northern locations selected by the government. The RCMP constables of the three communities were instructed by their superiors

to approach people whom they felt would be most amenable to the idea of moving, and to allay any fears they might have had. This should have been successful in attaining the number of families that were needed, but it was not. For some unknown reason only ten families were recruited; seven from Port Harrison and three from Pond Inlet. There were no volunteers from Cape Dorset.

Monetary assistance for obtaining supplies for the move came from the Eskimo Loan Fund which had been established earlier in the year to, "make loans to Eskimos for the purchase of supplies and equipment for approved projects which cannot be financed immediately by themselves or through other channels" (Department of Northern Affairs and National Resources, 1954: 26). The Inuit naturally needed transportation to their new homes, particularly as Craig Harbour lies 2250 km north of Port Harrison. Since the Eastern Arctic Patrol visited many northern locations during its journey in the region, it was only natural that it should fill this need. Therefore, the two vessels involved in the 1953 patrol, the CGS "C.D. Howe" and the CGS "d'Iberville" were instructed to pick up the volunteers during the scheduled stops at the two communities. On 29 August the vessels met at Craig Harbour and deposited four Port Harrison families and one Pond Inlet family at the local RCMP detachment which had been reopened in 1951. The three remaining families aboard the C.D. Howe were transferred to the d'Iberville to continue their voyage under Constable F. Ross Gibson who was to establish an RCMP post at Resolute.

At both locations the Inuit were placed under the supervision of the local RCMP detachment. These embodiments of southern Canadian law and order virtually controlled the lives of the native people. The constables were required to do all bookkeeping related to the returns from goods the Inuit produced or any wages they could obtain, in addition to handling all social assistance payments they might receive (Stevenson, 1977: 2). It is obvious that the government felt that the Inuit were incapable of monitoring their own lives.

The community at Craig Harbour was the first permanent settlement on Ellesmere Island in nearly five hundred years. Originally sighted by William Baffin in 1616, the island was named after the first Earl of Ellesmere in 1852. Its distance from major population centres often resulted in it remaining on the periphery of the national consciousness. However, the belief that game was sufficiently plentiful to support a small community, coupled with the theory that there were economic problems for the Inuit farther south, enabled the recently reestablished RCMP detachment to suggest that the area could be utilized by the Inuit. Thus, Canada's most northerly permanent settlement was established.

Unfortunately for those involved in the relocation, heavy ice conditions at Craig Harbour in mid-1953 impeded the hunting of seals and resulted in five families moving to Grise Fiord, eighty kilometers to the west. Three years later, the two RCMP officers stationed at Craig Harbour followed this example and transferred the detachment and remaining Inuit family to the new site.

The relocation to Resolute was apparently conducted for the same reason as that to Ellesmere Island. However, it would be naive to accept the premise that the plan was conceived solely for the benefit of the Inuit involved. Several facts tend to cast doubt on the government's motivation for supporting the project.

As previously noted, the Department of Northern Affairs and National Resources was concerned about game depletion in areas with large Inuit populations in the early 1950s and Port Harrison was identified as one such area. This belief apparently stemmed from the 1948 Eastern Arctic Patrol which reported that the region was overpopulated and lacked a sufficient base for native food requirements (Hammond, 1984: 2). However, only three years later, S.J. Bailey of the Eastern Arctic Patrol was able to report that:

> after carefully considering the reports received from the natives and white residents, I do not think that there has been an appreciable decline in the food resources of the area. Conditions do not appear to be any worse than they were thirty or forty years ago; the only difference is that the people themselves are less spread out. (Hammond, 1984: 3-4)

This statement was supported by the 1953 inspection tour of northern Quebec and southern Baffin Island by Alex Stevenson, who found that the situation at Port Harrison was improving:

> the economy of the natives of the Port Harrison region was fairly good during the past year. They had a fair fur year...This spring seals appear to be on the increase and the Eskimos were better off for meat than they have been for a number of years...The indication from all signs, such as an increase in snow-owls and lemmings is that next year will be a bumper year. (Hammond, 1984, Appendix 'A': 3-4)

During the course of his report, Stevenson also noted that several Inuit families had moved inland. This tends to support Bailey's assertion that the local conditions were due to the concentration of the native population rather than its size. Instead of relocating the people to the Arctic Islands, the government could simply have aided a move to the interior. Such a plan was instituted in 1957 when the local RCMP ordered all Inuit not employed to leave the settlement. A 1961 study showed that these people became less reliant on store food, clothes and yard goods than their counterparts in Port Harrison (Willmott, 1961: 40). If this policy had been initiated five years earlier, the Arctic relocation project would not have been necessary. Those who created the original plan for the move were obviously ignorant of the true situation at Port Harrison in the early 1950s, preferring to rely solely on out-dated information.

Government officials were also confused about the conditions at Resolute. A meeting of representatives of the Department of Resources and Development, the Royal Canadian Air Force, the RCMP and the Department of Transport, held on 10 August 1953 to discuss the relocations, raised a major concern regarding the area:

> *S/L O'Neil* (of the RCAF) stated that he was afraid that there was not sufficient wildlife in the Resolute area to provide for the proposed Eskimo population. *Mr. Cantley* (of DRD) replied that he had reason to believe that there was sufficient marine

> life to support Eskimo families concerned. *No one could say for sure that this was the case.* (Hammond, 1984, Appendix 'B': 3)

The fact that the government was supporting such a policy without sufficient knowledge of the locations involved would seem to indicate that there was more concern for the implementation of the plan than for the welfare of the participants.

This low level of concern, and confusion, seem to have affected many elements of the plan. As previously noted, various components of the scheme were changed prior to implementation. Indeed, only three months before the operation was scheduled to commence, F.J.G. Cunningham, the Director of the Northern Administration and Lands Branch of the Department of Resources and Development, wrote to the Department of Transport that plans for the relocation had not yet been completed (Hammond, 1984: 5). That this was the case although the plan had been discussed since the autumn of 1952 must call the government's true intentions into question.

The confusion surrounding the plan continued to the landing at Resolute. A large amount of supplies accompanied the Inuit aboard the d'Iberville and many seemed to be of questionable value. C.J. Marshall, the Secretariat of the Advisory Committee on Northern Development, wrote to fellow member G.W. Rowley that the shipment included many goods which the Inuit could have produced themselves or for which they had no use (Hammond, 1984, Appendix 'D-2': 3-4). Worse for the planners was the fact that there was a shortage of supplies valued at over one thousand dollars. Among the goods missing were 120 yards of tent material, 60 yards of khaki drill, 60 yards of blue denim, 40 yards of white duffle and one thousand board feet of lumber (Hammond, 1984, Appendix 'D-2': 5).

Another component of the relocation plan tends to raise doubt on the validity of the government's concern for the Inuit. Promises were made to the Port Harrison and Pond Inlet volunteers that they would be able to return home after two years if they were not satisfied with their new surroundings. These promises have been denied by the federal government in recent years as several inhabitants of Grise Fiord have requested a return to Port Harrison. However, in his report on the alleged promises, Marc Hammond did come to the conclusion that such statements were made (Hammond, 1984: 1).

These promises indicate that there were pressures influencing the relocation in addition to those stated by the government. A two year period is simply not long enough to determine if a relocation could be successful, therefore another problem, needing only a short term solution, had to be involved. This belief can be supported by the implementation of the plan itself. As noted previously, the government usually pursued a policy of assimilation in southern regions and this could have been attempted in 1953 in Port Harrison. The question which must be answered therefore, is what factor swayed the authorities to choose this relocation policy. In my opinion the key element motivating the St. Laurent government was the possibility of a threat to Canadian sovereignty in the High Arctic.

Such threats had occurred previously and plans were implemented which halted their chance of maturing. A notable example of this occurred in the early 1930s when interest in Arctic aerial routes and mineral developments was expressed by several countries. To forestall any claims to portions of the region a plan was formulated to transfer several Inuit families on Baffin Island, adversely affected by low fur prices, to locations farther north. In August 1934, the Hudson Bay Company vessel Nascopie stopped at Cape Dorset, Pangnirtung and Pond Inlet to take on volunteers, and then proceeded to Dundas Harbour. The fifty-seven particpants had agreed to a two year trial period for the relocation after which time they would be returned home if they so desired. During this time they were placed under the control of the HBC agent at Dundas Harbour. Under the 1934 agreement which permitted the HBC to establish a trading post on Devon Island, the company agreed to return the Inuit to their original homes at its own expense or to transfer them to other areas selected by the Department of the Interior if the post were closed (Jenness, 1964: 57). This accounts for the haphazard treatment which the Inuit subsequently received. Between 1935 and 1947 they were transferred to Croker Bay (1935), Arctic Bay (1936), Fort Ross (1937) and Spence Bay (1947) apparently because of ice conditions and administrative and economic interests. At no time were they given the option of returning home.

As in 1953, there was more involved in the relocation than a concern for Inuit welfare. James Montagne wrote that:

> there is the angle of occupation of the country, now that aerial routes, mineral developments, and other reasons make possible the claims of other countries to part of Canada's Arctic, which now reaches to the North Pole. To forestall any such future claims, the Dominion is occupying the Arctic islands to within nearly 700 miles of the North Pole. (Jenness, 1964: 58).

In the early 1950s there were two possible threats to Canadian sovereignty in the Arctic. The less worrisome was alluded to in a 2 February 1952 letter from H.A. Larson to the RCMP Commissioner:

> The advantage of placing our detachment directly across from Greenland would be that we then would have full control and supervision of Greenlanders and others travelling back and forth, and over the hunting activities they may engage in. As you know we had a Detachment (sic) established at Bache Peninsula in 1926, primarily for the maintenance of sovereignty. This Detachment (sic) was closed in 1933...I believe one mistake in connection with the Ellesmere Island Detachments (sic) in those days was the hiring of Greenland Eskimos exclusively (accompanied by their families) to act as hunters and guides for our own Detachments (sic)...Therefore if we could get a Detachment (sic) here (in the vicinity of Bache Peninsula), we should, in addition to the two Eskimo families employed permanently by the Police, endeavour to recruit three or four good Eskimo families from the Pond Inlet area to be transported up there for the purpose of

> trapping, hunting, etc. thereby in a general way improve their economic circumstances. (Hammond, 1984: 3).

More important than the improvement of economic circumstances for a few Inuit however, was the fact that the relocation would establish Canadian occupation and therefore sovereignty over the Arctic islands.

Danish reluctance to acknowledge Canadian sovereignty over Ellesmere Island had been going on for some time. In 1919 a Canadian request that musk-oxen hunters from Greenland be restrained from entering Ellesmere was disregarded by the unofficial Danish representative, Knud Rasmussen. He went so far as to say that the region was a "No Man's Land" (Morrison, 1985: 164), implying that Canada's sovereignty did not exist. This statement worried many officials in the Canadian government, with the result that plans were formulated in 1920 that would see the establishment of three RCMP posts, and the transfer of several Inuit families to Ellesmere Island. Two years later this was changed so that only one post was erected at Craig Harbour. Although it was transferred to Bache Peninsula only four years later, it did succeed in affirming Canadian sovereignty in the region. However, by the early 1950s the flow of Greenland hunters to the island again raised the possiblity that the Danish government might wish to question Canadian title to Ellesmere. Active occupation by the Inuit would not only place a barrier in front of the Danes, but also the more serious of the two threats — the United States.

The Second World War was a period of great cooperation between Canada and the United States. The Ogdensburg Agreement of August 1940, created the Permanent Joint Board of Defence and paved the way for such developments as the North-West Staging Route, the Alcan Highway and the Canol Project. Most Canadians gave these activities little concern. They did not perceive any possible threat to the country although such a threat did exist. In 1943, the British High Commissioner to Canada, Malcolm MacDonald, wrote of these projects:

> many influential American individuals who have had a hand in these developments in the North-West have no serious thoughts that the interests they represent shall withdraw. American money, energy and labour have been spent on an immense scale whilst the Canadians have comparatively little to do with some of the most important undertakings. (Diubaldo, 1981: 95)

The Canadian government only recognized the threat of a permanent American presence in the North because of MacDonald and instituted a plan whereby the country would purchase the American interests in the projects. While Canada escaped the inherent dangers of cooperating with the ambitions of the U.S., the example set by the projects created an aversion to the presence of the Americans in the Arctic. The possibility of a decrease in Canadian sovereignty led to an increasing wariness of American ideas regarding the region.

The immediate post-war years saw the U.S. place increased importance on the establishment of defensive capabilities in the Arctic because of the threat of a Russian attack on America through the region. Such paranoia led to the proposal, of 1 May 1946, for the construction of five American operated weather stations, and the requests to organize a naval exercise for the area and to increase cold weather research. After a meeting, on 18 May 1946, with representatives of the American government to discuss these matters, the Canadian delegation remained to express their opinions. The primary concern of most of the gentlemen present related to sovereignty. A representative of the Department of Mines and Resources succinctly presented the problem when he noted that these weather stations would be located in parts of the Arctic where the Canadian claim was weak, and that therefore:

> it would seem rather unwise from the point of sovereignty to authorize the Americans to enter into independent occupation of these weather stations. (Pierce, 1976: 55)

It was eventually decided that the best method of dealing with these requests was to circulate a draft paper to various officials in the government, advising them of the situation and asking for their opinion on what course of action should be taken. The Minister of Mines and Resources replied that his department was concerned about the implications of permitting another country to establish installations in the area, particularly as the stations would be built where, "Canada has hitherto been able to do little by recognized methods of occupation to reinforce her claims to sovereignty" (Pierce, 1976: 55–6). Similar fears were expressed in a memorandum from the Department of National Defence to the Cabinet Defence Committee which stated that because Canada's claim to much of the Arctic was not supported by effective occupation or development, the establishment of permanent foreign interests, "would be attended by a subsequent weakening of Canada's sovereignty" (Page, 1977: 1558). The Department of National Defence advised that if Canada wanted to maintain its claim to the area in the face of the American requests;

> then it follows that she must be prepared to carry out such developments by herself or with a calculated degree of assistance. In brief, Canada must now either herself provide essential facilities and services in her Arctic territories or provide them co-operatively, or abandon almost all substantial basis to her claim upon them. (Diubaldo, 1981: 99)

The fact that the U.S. expected quick confirmation of these requests to invade the Arctic was acknowledged in the House of Commons on 19 July 1946, when it was announced that newspaper advertisements had already been authorized by the American government, asking for, "applications to work for the United States in the Arctic regions of Canada" (Debates of the House of Commons, 1946: 3606).

Canadian authorities were placed in a very difficult position. They did not particularly want Americans in the north because of past experience, but they did have to be seen occupying the region or else the U.S. might attempt to claim the responsibility. Finally deciding that cooperation with the Americans would at least result in a tacit acknowledgement of Canadian sovereignty, the government announced that a joint army-air force-scientific exercise would commence in 1946 and a winter warfare centre would be established at Churchill, Manitoba. On 12 February 1947, a joint statement was issued by the two countries announcing the

continuation of defence collaboration in the future. Less than one month later, on 4 March 1947, C.D. Howe, the Minister of Reconstruction and Supply, rose in the House of Commons and stated:

> To enable Canada to provide more accurate and long range weather forecasting to meet her domestic and international obligations, the government proposes to establish nine weather stations in the Arctic in the next three years...These new weather stations will be of great value to the United States as well as Canada...The United States has therefore undertaken to assist Canada in the establishment and operation of these northern stations, which will, of course, be under the control of the Canadian government...United States technical personnel will be included in the staffs required. The Canadian government is grateful for this assistance, which will be invaluable until sufficient technically qualified Canadian-trained personnel are available. (Debates of the House of Commons, 1946: 989–90)

Canada would provide the permanent buildings for the installations as well as the base commander, while the executive officer and half the personnel would be American. Later, the plan was scaled down to five stations to be located at Eureka and Alert on Ellesmere Island, Isachson (Ellef Ringnes Island), Mould Bay (Prince Patrick Island) and Melville Island. This last station was eventually established at Resolute Bay due to heavy ice conditions at Melville Island in the summer of 1947. Canada had managed to stave off the American threat yet again, but the danger was still present. With the Russian detonation of a hydrogen bomb in 1950, the problem came to the fore yet again.

The years after 1950 saw repeated calls for an early warning system in the Arctic because of the possibility of a Soviet attack. A 1951 defence study commissioned by the U.S. government, in which Canada was only an unofficial participant, first stated this need. One year later, the Lincoln Summer Study called for the construction of a Distant Early Warning system of two radar lines in Canadian territory. Yet again the American government showed its true colours with regard to Canadian sovereignty over the Arctic region. Although the administration of Prime Minister St. Laurent was still debating the scheme, the United States Air Force contracted with the Western Electric Company to carry out a major study of the difficulties related to the construction, operation and maintenance of a system of this type (Sutherland, 1966: 239). In 1954 the federal government did agree to the DEW Line plan, but only after the U.S. had officially recognized Canada's sovereignty in the north.

During the years prior to the DEW Line agreement fear for Canadian sovereignty in the Arctic reached a peak. It cannot therefore be a coincidence that the Inuit relocation was carried out in this period, particularly as both Ellesmere and Cornwallis Islands were the sites of weather stations. Throughout 1953 the issue of sovereignty repeatedly came to the fore in print and political debates. In the 27 June 1953 edition of *The Financial Post*, Michael Barkway wrote:

> Canada's claim to all the land up to the North Pole is being tested more seriously than ever before. Defence developments are forcing the pace. The United States press is beginning to write about the Arctic as though it were a U.S. discovery which had never been touched until the present defence drive took the U.S. services there...it is irritating...to find influential U.S. magazines solemnly declaring, 'The United States is not the only country to explore the Arctic.' (Barkway, 1953)

The real problem, as identified in the Barkway article, was that the American government had never acknowledged the method by which Canada claimed the Arctic Islands. Whereas this country used, and continues to use, the sector theory which extends the Alaska-Canada boundary to the North Pole, thus awarding the country all the islands west of Greenland, the U.S. only recognized sovereignty on the basis of active occupation. In most cases there were no Canadian citizens permanently settled in the far north and therefore the Americans believed that Canada was not actively fulfilling its duties in the region. The only way to ensure effective occupation was to permanently settle Canadians on the islands.

In federal circles, the occupation of the Arctic became a major political issue. The minutes of the previously noted meeting of 10 August 1953 held to discuss the relocation state:

> *Mr. Sivertz* (of the DRD) pointed out that the Canadian government is anxious to Have (sic) Canadians occupying as much of the north as possible and it appeared that in many cases the Eskimos were the only people capable of doing this. (Hammond, 1984, Appendix 'B': 3)

Four months later, Prime Minister St. Laurent said in the House of Commons that, "*We must leave no doubt about our active occupation and exercise of our sovereignty in these lands right up to the pole*" (Debates of the House of Commons, 1953–4: 700). To ignore these two statements and view the relocation simply as an attempt to rescue a small number of Inuit from a life of apparent hardship is naive and foolish.

Later reports also support the theory that the relocation had a great deal more to do with sovereignty than has been acknowledged. A 1960 memo summarizing the move to Resolute stated that it served, "a useful purpose, in confirming in a tangible manner, Canada's sovereignty over this vast region of the Arctic" (Kemp et al, 1977: 42). Alex Stevenson must have had this in mind when he wrote that the relocation to Ellesmere Island, "served a distinct purpose in confirming in a tangible manner Canada's sovereignty over this vast region of the Arctic" (Stevenson, 1977: 84). Anna Nungaq, an original participant in the scheme, recalled in a 1981 interview:

> Apparently we were brought up there to keep other interested countries from taking possession of the land...They (the government) were desperate to settle people up there to establish sovereignty over the land. (*Inuktitut*, 1981, 6–7)

Two newspaper articles published in 1983 also state that the Inuit were relocated to the new settlements because of problems related to sovereignty (Goddard, 1983; Samjanovs, 1983), and not because of any great humanitarian motives.

While the evidence I have presented supports my claim that sovereignty was the major force influencing the 1953 relocation, few of those who have studied the event have placed the same emphasis on it. Many who have written on the relocation (Freeman, 1969 and 1984; Diubaldo, 1985; Jenness, 1964; Bruemmer, 1968) have either ignored the issue of sovereignty or have not acknowledged its primacy. They have ignored the fact that the federal government has rarely implemented policies solely for the benefit of the Inuit. The presence of Ottawa has most often been felt in the region when there has been the opportunity to increase revenues or when Canadian sovereignty was being threatened. In the early 1950s, the government's decision to move the Inuit to remote Arctic locations was motivated by such a threat.

Acknowledgments

I would like to thank Profs. Bruce Hodgins and Shelagh Grant of Trent University for assistance and encouragement offered during the researching and writing of this paper.

References

Barkway, M. While we let U.S. take over the Arctic. Financial Post, 27 June 1953, p. 7.

Bruemmer, F. Eskimos of Grise Fiord. Canadian Geographic Journal, 77(2):64–71.

Canada. Department of Northern Affairs and National Resources, Annual Report, 1953–4. Ottawa: 1954.

Canada. Official Report of the Debates of the House of Commons. Second Session-Twentieth Parliament, Volume IV, 1946. Ottawa: Edmund Cloutier, 1947.

Canada. Official Report of the Debates of the House of Commons. First Session-Twenty-Second Parliament, Volume I, 1953–4. Ottawa: Edmund Cloutier, 1954.

Diubaldo, R.J. The Government of Canada and the Inuit, 1900–1967. Ottawa: Indian Affairs and Northern Development, 1985.

Diubaldo, R.J. The role of the Arctic Islands in defence. In: Zaslow, M., ed. A Century of Canada's Arctic Islands, 1880–1980. Ottawa: The Royal Society of Canada, 1981, 93–110.

Freeman, M. Adaptive innovation among recent Eskimo immigrants in the eastern Canadian Arctic. The Polar Record, 14(93):769–81.

Freeman, M. The Grise Fiord Project. In: The Handbook of North American Indians, Vol. 5, Arctic. Washington: The Smithsonian Institute, 1984, 676–82.

Goddard, J. Inuit at Grise Fiord outsiders, too. Globe and Mail, 8 September 1983, p. 7.

Hammond, M. Report on Findings of an Alleged Promise of Government to Finance the Return of Inuit at Resolute and Grise Fiord to Their Original Homes at Port Harrison (Inukjuak) and Pond Inlet. Ottawa: Department of Indian and Northern Affairs, 1984.

Inuktitut asks Anna Nungaq about moving to Grise Fiord. Inuktitut, 49(1981):5–14.

Jenness, D. Eskimo Administration: II. Canada. Montreal: Arctic Institute of North America, 1964.

Kemp, W.B., G. Wenzel, N. Jenson and E. Val. The Communities of Resolute and Kuvinaluk: A Social and Economic Baseline Study. 1977.

Morrison, W.R. Showing the Flag: The Mounted Police and Canadian Sovereignty in the North, 1894–1925. Vancouver: University of British Columbia Press, 1985.

Page, D.M. ed. Documents on External Relations, Volume 12, 1946. Ottawa: Supply and Services, 1977.

Pierce, C.J. Sovereignty as an Issue in Canadian Defence Policy. M.A. Thesis, Department of Political Science, University of New Brunswick, 1976.

Samjanovs, R. Canada's northernmost community looks east for Inuit ties. News/North, 19 August 1983, p. B1.

Stevenson, A. Inuit Relocation — High Arctic. 1977. (A document from the files of the Department of Indian and Northern Affairs).

Sutherland, R.J. The strategic significance of the Canadian Arctic. In: R.St.J. MacDonald, ed. The Arctic Frontier. Toronto: University of Toronto Press, 1966, 256–278.

Willmott, W.E. The Eskimo Community at Port Harrison P.Q. Ottawa: Department of Northern Affairs and National Resources, 1961.

REPRÉSENTATIVITÉ INUIT AU SEIN DES POSTES DE GESTION DANS LES TERRITOIRES-DU-NORD-OUEST: DE LA THÉORIE À LA PRATIQUE

Claire Mailhot

Canadian Studies, Carleton University, Ottawa, Ontario K1S 5B6

Niveau: Maîtrise

Résumé

La population inuit est jeune, la moitié d'entre elle a moins de 20 ans; cela signifie que chaque année bon nombre de jeunes joignent le marché du travail. Cette donnée est importante, car bien que le chômage soit pratiquement inexistant dans les communautés inuit depuis plus d'une génération, son taux actuel est de beaucoup supérieur à la moyenne nationale et celui-ci ne cesse d'augmenter.

Si les Inuit ne se trouvent pas de travail, ce n'est pas seulement à cause d'une penurie d'emplois dans leurs communautés mais principalement à cause du manque de qualifications de la main d'oeuvre. En effet, très peu d'Inuit ont complété leurs études secondaires et les emplois qu'ils peuvent assumer se situent franchement à la base de la hiérarchie du pouvoir décisionnel. Par contre les gouvernements fédéral et territorial, les principaux employeurs dans le nord, font appel à la main-d'oeuvre qualifiée du Sud.

Afin de remédier à cette situation, les deux paliers gouvernementaux ont mis sur pied de nombreux programmes de formation mais ceux-ci, selon l'avis des organismes inuit, sont loin d'être suffisants et adéquats. Pour qu'ils soient efficaces, il est essentiel de développer une stratégie d'emploi à long terme en tenant compte de la réalité culturelle des Inuit.

Bien que la collaboration entre les organismes gouvernementaux et inuit qui s'amorce semble très prometteuse, les résultats obtenus jusqu'à maintenant ne sont pas encore

probants. En attendant, la demande de main-d'oeuvre d'inuit qualifiés se fait de plus en plus pressante afin de pouvoir répondre aux critères d'équité en matière d'emploi et de représentativité de la population inuit.

Mots-clés: Territoires-du-Nord-Ouest, Inuit, gestion gouvernementale, emploi, chômage, éducation, stress sociaux, culture, stratégie d'emploi, Nunavut.

Abstract

The Inuit population is young, half of it being under 20, which means that every year a large number of young people are added to the labour force. This is an important fact, for, while unemployment was practically non-existent in the Inuit communities a generation ago, the current rate is considerably above the national average and it is still rising.

The fact that the Inuit do not find work is not solely due to the lack of employment opportunity in their communities; the main reason is that they do not have the necessary qualifications. Very few Inuit have finished high school, so that the jobs available to them are occupations at a low level where there is no decision-making power. On the other hand the federal and territorial governments, which are the principal employers in the North, have to bring in their qualified work force from the South.

In an attempt to remedy this state of affairs the two levels of government have launched numerous training programs which, are, however, seen by Inuit organizations as being quite inadequate. Effectiveness depends on the development of a long-term employment strategy which takes into consideration the realities of Inuit culture.

Although, in theory, the first move towards cooperation between government and Inuit organizations looks very promising, it is still far from being solidly established. In the meantime, the demand for qualified Inuit workers is becoming an increasingly urgent matter, because of the need to meet the criteria of fair employment practice and Inuit representation.

Key words: Northwest Territories, Inuit, management by government, employment, unemployment, education, social stress, culture, employment strategy, Nunavut.

Introduction

Mise à part la participation de la Gendarmerie Royale du Canada, ce n'est que depuis une trentaine d'années que le gouvernement fédéral assure une présence permanente de ses fonctionnaires dans l'Arctique Canadien. Cette récente affiliation dans les communautés inuit des Territoires-du Nord-Ouest (T.N.O.) s'est produite à un rythme accéléré et la population inuit doit constamment s'adapter à ces nouveaux changements.

Le passage en moins d'une génération d'une économie de chasse à une économie d'emploi rémunéré, s'accompagne de nombreux stress sociaux. L'un des plus important est la situation de l'emploi; le chômage pratiquement inconnu il y a trente ans dépasse maintenant de cinq fois le taux national.

Pour pallier à cette situation, de nombreux programmes gouvernementaux ont été mis sur pied afin de favoriser l'embauche des Inuit au sein des gouvernements fédéral et territorial. Cependant malgré de nombreux efforts, le taux de chômage ne cesse d'augmenter car peu d'Inuit possèdent les qualifications requises pour combler les emplois disponibles.

Les organismes inuit également s'intéressent beaucoup à cette question, car même si le bassin de main-d'oeuvre est sous-utilisé dans les communautés inuit des T.N.O., il est nécessaire d'importer des Blancs du sud pour combler les postes de direction. Ces gens vont dans le nord habituellement pour une courte période, ils connaissent peu la culture et la langue des Inuit, ce qui entraîne beaucoup de frustrations de part et d'autre.

De plus, les organisations inuit s'inquiètent de l'emprise extérieure des décisions qui les affectent, c'est pourquoi ils demandent qu'on transforme les T.N.O. en un nouveau territoire: le Nunavut. Des négociations sont actuellement en cours afin d'évaluer si les T.N.O. sont prêts pour un tel changement, ce qui leur donnerait un pouvoir décisionnel se situant à mi-chemin entre celui des territoires actuels et celui des provinces.

Le but de cet exposé est d'analyser la situation de l'emploi des Inuit des T.N.O. dans les postes de gestions fédérales et territoriales et de voir s'il est possible d'améliorer la situation. Cette orientation est doublement importante par le fait que, d'une part, les décisions affectant le mode de vie de la population inuit proviennent en majorité des services gouvernementaux et, d'autre part, parce que les gouvernements fédéral et territorial représentent actuellement les principaux employeurs dans les communautés inuit.

Il est important de garder en mémoire qu'il est très difficile d'isoler la situation de l'emploi dans un contexte culturel différent de celui qui prévaut dans l'ensemble du Canada. Pour tenter de comprendre et d'améliorer la situation de l'emploi, il est essentiel de regarder également les programmes de formation et d'éducation offerts aux Inuit. De plus, compte tenu du fait que la culture du sud est fort différente de celle du nord sur les plans politique, économique et social, les discussions sur le sujet de l'emploi ne sont pas faciles.

Cependant, il semble que pour obtenir une situation satisfaisante tant pour les Inuit que pour les gouvernements, il soit essentiel que les deux parties cessent de travailler séparement et collaborent ensemble à une stratégie d'emploi à long terme respectant la réalité culturelle des Inuit.

Une telle démarche a été entreprise récemment par un groupe de travail, formé en 1984, qui vient de terminer un premier rapport portant sur une «stratégie de développement de la gestion à caractère inuit» (Report of the Task Force, 1986). Il reste à espérer que cette première tentative réelle de collaboration entre les dirigeants inuit et le gouvernement territorial recevra l'appui financier nécessaire à sa réalisation et ceci pour le bienfait des deux parties.

Situation actuelle

> «Il était une fois un singe et un poisson qui furent surpris par une forte inondation. Agile et souple, le singe trouva refuge en grimpant dans un arbre. En regardant le flot torrentiel au-dessous de lui, il vit un poisson qui se débattait contre le courant rapide des eaux. Poussé par un désir charitable

d'aider son infortuné compagnon, il se pencha et sortit le poisson de l'eau. À la surprise du singe, le poisson ne lui fut pas reconnaissant de son geste.»

Fable Orientale.

Éléments de base

Les années 50, ont marqué le début d'une ère de modifications importante pour les Inuit des T.N.O. Vivant jusque là principalement d'une économie de chasse et de pêche, les Inuit ne connaissaient les hommes blancs que par les comptoirs de traite, les agents de la Gendarmerie Royale et les missionnaires.

Depuis, la situation a changé radicalement; les Inuit vivent maintenant dans de petites communautés très bureaucratisées et ont besoin de ressources financières pour faire face aux coûts croissants occasionnés par un mode de vie qu'ils ont été forcés d'accepter. Le chômage inexistant il y a une génération est aujourd'hui un phénomène presque normal, puisqu'il affecte les trois-quarts de la population en certains endroits.

En 1984, le Bureau de Statistique du Gouvernement des T.N.O. mentionnait que le taux de chômage chez les Inuit des T.N.O. était de 28% comparé à 7% pour les allochtones. Cependant, cette image est basée sur un taux de participation de la population active de 52%, signifiant que la moitié de la population inuit est considérée comme exclue du milieu du travail (Nunasi Corporation, 1985).

Avec un tel profil de l'emploi, les jeunes ne voient pas d'avantages à poursuivre leurs études et abandonnent l'école sans avoir obtenu de diplôme. Au cours des cinq dernières années, 17 Inuit seulement ont terminé leurs études secondaires dans les T.N.O. (Report of the Task Force, 1986). Sans travail et sans argent, les Inuit et plus particulièrement les jeunes, sont très frustrés. N'ayant rien à faire et pas d'endroit où aller, il n'est pas surprenant que l'abus d'alcool et de la drogue de même que les taux de criminalité et de suicide aient atteint un niveau dépassant de beaucoup la moyenne nationale.

La situation est alarmante car les Inuit semblent entraînés dans un cercle vicieux. Le chômage est à la base des problèmes sociaux et c'est souvent à cause de ces mêmes problèmes qu'ils ne peuvent se trouver du travail. Mike Bell du département des services sociaux illustre bien cette réalité en mentionnant: «There is not one problem; there are a number of them, interconnected, interrelated, all tangled up in some fishing line. And, if you've ever had this problem. . . you will know that pulling hard on one hook only creates more of a problem. It simply creates more pressure on the whole mess. The only way to deal with tangled fishooks — and with social problems — is to carefully, patiently, sort them out together.» (1985, p. 10). Alors par où debuter? Comment briser ce cercle ou le chômage contribue à la croissance des problèmes sociaux, entraînent eux-mêmes une augmentation de la main d'oeuvre venant du sud pour répondre à la hausse des services spécialisés occasionnés par ces problèmes, alors que la présence des spécialistes blancs contribue directement ou indirectement à augmenter le stress social. . .

Il n'est pas facile de bien comprendre et bien juger la situation de l'emploi dans le nord où prévaut une culture très différente de la nôtre. Depuis quelques années, les gouvernements fédéral et territorial ont instauré des programmes d'accès equitable à l'emploi. Par contre ceux-ci ont eu bien peu de succès car la majorité des Inuit n'ont pas la formation nécessaire pour combler les postes disponibles.

Réalité culturelle inuit

Les organismes inuit sont conscients du fait que l'ensemble de cette situation repose sur une base culturelle et que toute mesure visant à l'améliorer doit, pour réussir, tenir compte de la réalité culturelle inuit. C'est pourquoi, comme le mentionne un rapport de l'organisation nationale des Inuit «Inuit Tapirisat of Canada» (I.T.C.): «Inuit have over the past decade been struggling to regain control over their lives, both through land claims negotiations and through the implementation of systems of self-government.» (I.T.C., 1985, p. 2).

L'objectif des dirigeants inuit est d'avoir un contrôle sur les décisions politiques, économiques et sociales qui affectent leur mode de vie. Pour ce faire, il est essentiel que les Inuit aient une meilleure représentativité au sein des postes de gestion. Mais le but ultime est la reconnaissance d'un nouveau territoire dans les T.N.O. Ce territoire porterait le nom de «Nunavut» signifiant «Notre Terre» et comprendrait les régions à population majoritairement inuit, c'est-à-dire celle de Baffin, du Keewatin et de Kitikmeot (Fig. 1).

Ce territoire a une population de 20 000 habitants composée de 85% d'Inuit dont 50% sont agés de moins de 20 ans. Bien que les Inuit soient majoritaires, ils ont très peu de contrôle sur les décisions qui les concernent. En fait, moins de 50% d'entre eux travaillent pour les gouvernements fédéral et territorial et ils occupent des emplois de bas niveau, moins bien rémunerés et ayant peu de pouvoir décisionel.

Avec 300 nouveaux jeunes qui joignent les forces de travail chaque année, le taux de chômage ne cessera d'augmenter dans l'avenir. Si des mesures sévères ne sont pas prises bientôt, la situation de crise qui prévaut actuellement prendra des proportions difficilement contrôlables. Déjà la spécialisation des emplois rendent ceux-ci difficilement accessibles pour la population inuit qui dépend donc de plus en plus du gouvernement. Ainsi, le véritable problème n'est pas le manque de travail mais plutôt le manque de qualifications pour obtenir les emplois disponibles.

C'est pourquoi la priorité actuelle devrait être mise sur les programmes de formation des Inuit afin de les préparer à l'emploi. De plus, avec la nouvelle politique du gouvernement fédéral concernant l'égalité d'accès à l'emploi, il semble que ce soit dans le domaine de la gestion que la demande est la plus pressante. D'autant plus que les deux paliers gouvernementaux sont les principaux employeurs dans les T.N.O.

Ce besoin est reconnu par le groupe de travail qui mentionne: «Il y a un manque de programmes de formation et d'opportunités pour les Inuit dans le secteur public mais il n'y a pas de pénurie d'emplois. Seulement par attribution, plusieurs centaines de postes de moyenne et supérieure gestions pourraient être disponibles pour les Inuit qualifiés

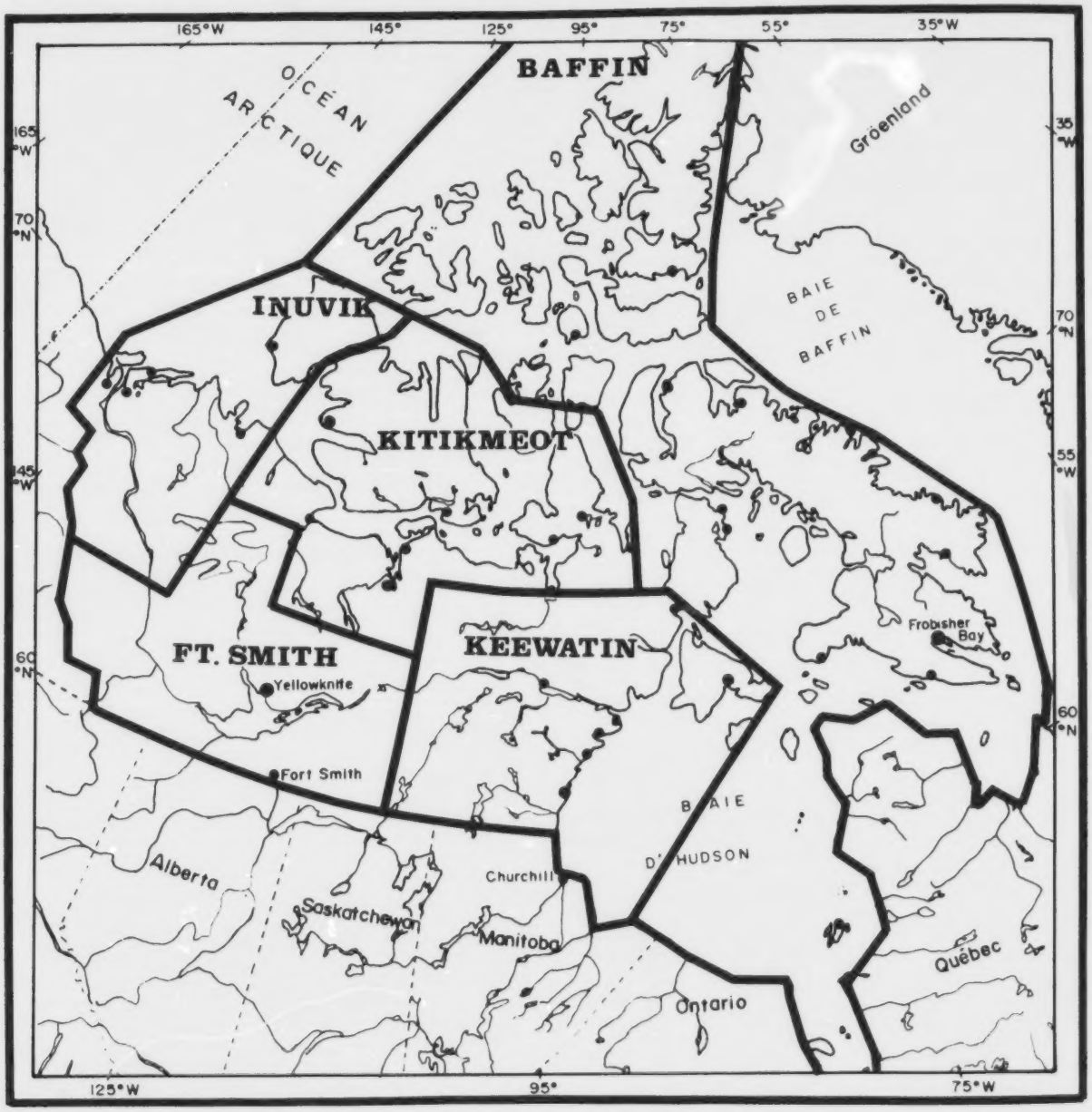


Figure 1. Les régions administratives des T.N.O.

dans les cinq prochaines années.» (Report of the Task Force, 1986, p. 5). Ainsi la demande d'Inuit qualifiés est grande actuellement et elle serait fortement accentuée advenant la formation du Nunavut.

Les programmes de formation

> «Donne un poisson à un homme, il sera rassasié pour un jour. Montre à cet homme comment pêcher, et il ne connaîtra plus la faim.»
>
> Proverbe Chinois.

Présentement, il y a deux principales orientations des programmes de formation pour l'emploi, celle des gouvernements fédéral et territorial d'une part et celle des organisations inuit d'autre part.

L'approche des gouvernements fédéral et territorial

Pour leurs parts, les deux paliers gouvernementaux sont principalement préoccupés par la bonne gestion des T.N.O. de même que d'offrir des services de bonne qualité aux Inuit.

Pour ce faire, ils ont besoin de personnel qualifié et ils orientent leurs programmes de formation en fonction du système déjà en place.

Dans cette optique, plusieurs programmes de formation sont disponibles dans différentes institutions post-secondaires et aux trois niveaux gouvernementaux (fédéral, territorial et régional). Cependant de l'avis des Inuit: «However, with few exceptions, these training opportunities are designed for low level entry into the workforce — clerical, technical and manual job postings. For the most part, the present training system reinforces class distinctions and promotes institutional racism wherein the often transient, non-native employee rises quickly while the native northerner is destined to menial work at the bottom end of the job market.» (Stiles, 1984, p. 16).

Parmi ces exceptions il y a lieu distinguer le programme «Northern Careers», une initiative de la Commission des Services Publics Fédérale, qui a comme objectif de former les autochtones pour des emplois permanents de moyenne classe dans les services civils fédéraux. Ce programme a l'avantage d'être assez flexible dans son fonctionnement, combinant des cours et des stages de travail dans une variété de domaines.

Cependant, bien que ce programme existe depuis quelques années avec les Indiens et les Métis plus au sud, il semble que les dirigeants du programme Northern Careers aient de la difficulté à recruter des Inuit ayant une éducation suffisante de 10–12^{e} année. Dans la région de Baffin, les premiers étudiants de ce programme viennent de terminer leur première année d'un programme de deux ans. Il est donc trop tôt pour juger la qualité de ce programme avec les Inuit qui semble une bonne initiative mais: «These programs serve the immediate priorities of the federal government.» (Stiles, 1984, p. 21).

Une récente initiative territoriale consistant en la mise en place de l'«Arctic College» à Frobisher Bay est très prometteuse. Ce collège est la seule institution post-secondaire située dans l'arctique de l'est. Cela signifie que depuis 1984, les Inuit n'ont plus à ce rendre dans le sud, à Churchill ou à Fort Smith, pour recevoir leur éducation et leur programme de formation. Cependant ce n'est que depuis le mois de janvier 1986 qu'un programme d'Études Administratives a débuté (Nunasi Corporation, 1986).

Il semble donc que le gouvernement fédéral soit enclin à promouvoir la formation des Inuit mais il n'en est qu'au stade préliminaire et beaucoup d'efforts restent à faire pour vraiment améliorer la représentativité des Inuit au sein des postes de gestion de son gouvernement. Conscients de cette lacune, les organismes inuit préparent leurs propres programmes de formation.

L'approche des organismes inuit

Devant la lenteur des modifications, les organismes inuit s'impatientent, eux-mêmes doivent engager du personnel allochtone par manque de personnel inuit qualifié. De plus, avec les négociations concernant la réclamation des Terres et le Nunavut qui progressent rapidement, les dirigeants inuit des T.N.O. veulent se préparer advenant une division des Territoires.

De là l'origine de la seconde approche des programmes de formation principalement dirigée par l'I.T.C. Cette approche a une vision beaucoup plus globale de la situation de l'emploi; elle favorise entre autres la coordination des différents organismes inuit en vue de promouvoir une stratégie de développement de la gestion à caractère inuit. Dans cette optique, un rapport a été effectué en 1984 par Mark Stiles et cie pour l'I.T.C. Ce rapport intitulé «Nunasi Aulatsininga», exprime l'opinion ferme des dirigeants inuit et de leurs besoins immédiats pour une augmentation du personnel inuit qualifié.

Le rapport est basé sur la notion de «développement de la gestion» qui implique un processus allant au-delà des modèles traditionnels de formation en gestion, c'est-à-dire de la division hiérarchique des classes de travail sur laquelle est basée la société capitaliste mais qui n'existe pas dans la société inuit. Ainsi par développement de la gestion ils entendent une série de mesures visant une efficacité organisationnelle, orientée vers l'amélioration des organismes par opposition aux programmes favorisant seulement le développement des aptitudes individuelles (Stiles, 1984).

Un de leurs arguments est que les gouvernements devraient investir davantage sur la formation des Inuit dans les domaines de la gestion plutôt que sur la formation des non-Inuit. En effet, des sommes importantes sont consacrées à la formation des fonctionnaires du sud alors que la majorité d'entre eux ne sont pas intéressés à demeurer longtemps dans le nord.

Actuellement il y a un urgent besoin d'Inuit qualifiés pour travailler au sein des deux paliers gouvernementaux et des organismes inuit. Advenant la division des Territoires, le manque de main-d'oeuvre inuit ferait en sorte que le contrôle du Nunavut serait le prolongement de la situation présente. D'après l'expérience de l'Alaska, du Groënland, du Nord du Québec et de toutes les Nations en développement du Tiers-Monde, il ressort que: «Without a well-trained body of indigenous people at the middle-management level of government, influence and control will always be seen to rest in the hands of «outsiders».» (Stiles, 1984, p. 25).

Bien que les recommandations proposées dans ce rapport n'ont pas été suivies, sa parution a eu un impact très important en permettant pour la première fois une réunion regroupant les principaux dirigeants inuit et gouvernementaux. De cette réunion est né le groupe de travail sur la stratégie du développement de la gestion à caractère inuit.

Ce groupe de travail est le premier qui traite de manière prioritaire des programmes de formation dans une perspective à long terme. Le bilan de leurs rencontres semble très positif si l'on en juge d'après le premier rapport paru en avril 86 et qui s'intitule «A Strategy for Inuit Management Development». Ce dernier se résume brièvement par le financement à long terme des programmes de formation visant à augmenter le nombre d'Inuit dans les postes de gestions moyenne et supérieure, tout en respectant le contexte politique, économique et culturel des Inuit. Cependant il est encore trop tôt pour pouvoir juger de la portée de ce projet.

Outre l'I.T.C. et le groupe de travail, d'autres organismes inuit ont leurs propres programmes de formation mais seul celui des Co-op de l'Arctique est désigné spécifiquement pour la formation de gestionnaires inuit. La difficulté est que cet organisme indépendant fonctionne avec un budget très restreint alors que les coûts de formation dans le nord sont

très élevés. En effet, lorsque tous les frais de transport, d'hébergement et de formation sont accumulés, il en coûte entre 26 000 $ et 60 000 $ par étudiant par année (Nunasi Corporation, 1985).

Il est donc très difficile de faire fonctionner des programmes planifiés à long terme alors que le financement que reçoit l'organisme est sur une base annuelle. De plus, un autre organisme, le Nunasi, a effectué une longue étude en 1985 afin de répondre à ses besoins urgents de main d'oeuvre inuit à court, moyen et long terme. Pour ce faire, l'étude suggérait un programme condensé de formation des étudiants inuit afin de réduire le processus habituel d'éducation qui demande de 10 à 15 ans avant d'obtenir un personnel qualifié. Cependant, ce programme reste inutilisé car il n'a pas reçu de financement (Nunasi Corporation, 1985).

Perspectives d'avenir

> «L'égalité sans différenciation, est une mauvaise égalité. La différenciation sans égalité, est une mauvaise différenciation.»
>
> Proverbe Oriental

Équité en matière d'emplois

En 1972, le ministre Jean Chrétien présentait les objectifs fixés par le gouvernement canadien dans «Le Nord Canadien 1970–1980». Parmi ces objectifs on retrouvait notamment les suivants:

«Améliorer le niveau de vie et la qualité de vie des habitants des régions nordiques par des mesures qui respectent leurs préférences et leurs aspirations, et leur garantir l'égalité d'accès à l'emploi.» (Jacobs, 1981, p. 16).

Depuis, quatorze années se sont écoulées et outre la partie concernant l'amélioration du niveau de vie, cet objectif n'a été que partiellement réalisé. En effet, si l'on tient compte des problèmes sociaux, il est douteux que la qualité de vie soit meilleure actuellement et peu de mesures ont été entreprises pour permettre aux Inuit d'obtenir l'égalité à l'emploi, tout particulièrement en ce qui a trait à leurs aspirations.

Par contre, le thème portant sur l'égalité d'accès à l'emploi est un sujet à la mode actuellement. Le dépôt en juin 85 du projet de loi C-62 concernant la mise sur pied de programmes d'équité en matière d'emploi dans toutes les sociétés relevant de la compétence fédérale, en est le plus récent exemple:

> «Aux termes de ce projet de loi, les sociétés visées seraient tenues de prendre des mesures en vue de remédier aux inégalités en matière d'emploi dont sont victimes certains groupes bien précis au sein de la société canadienne, à savoir les femmes, les autochtones, les personnes handicapées et les minorités visibles.» (Rapport du Comité Parlementaire, 1985, p. 117).

Ce projet de loi reconnaît qu'il faut éviter le gaspillage des ressources humaines entraîné par les pratiques discriminatoires, et qu'il est plus avantageux économiquement de favoriser l'équité en matière d'emploi plutôt que de maintenir le coût des programmes sociaux.

Cependant, la réponse de l'I.T.C. au comité législatif laisse clairement voir le point de vue inuit sur ce projet de loi: «The Bill C-62 is in no way able to take into account the implications of culture, northern economic conditions, the political objectives of Inuit or environmental and geographic factors. Bill C-62, as with many other government initiatives, was formulated with southern social and economic conditions in mind, and as such does not 'fit' the northern reality.» (I.T.C., 1985, p. 9).

Une rencontre avec M. Rob Higgins de l'I.T.C. explique davantage ce point de vue en mentionnant que: «Le gouvernement utilise pour les Inuit les mêmes solutions que pour les autres groupes cibles alors que la problématique inuit est complètement différente. Les femmes et les personnes handicapées ont le même accès à l'éducation que l'ensemble de la société et ces groupes demandent à être integrés. Les Inuit par contre ont une culture propre et veulent contrôler leur mode de vie sans être absorbés par la société dominante avec laquelle les Inuit ne peuvent rivaliser au point de vue de l'éducation.»

Rien de cela n'est inclus dans le projet de loi C-62. De même, le récent rapport du groupe d'études du ministre Nielsen dans la section concernant l'emploi des autochtones, n'amène aucun élément nouveau susceptible d'améliorer cette situation.

Planification à long terme

Depuis plusieurs année, l'I.T.C. consacre beaucoup d'efforts au problème de l'emploi dans le nord. À force de chercher des solutions à long terme, ils ont dégagé deux points particulièrement importants:

«First, it is unrealistic to attempt to remedy one element of the overall situation without also considering other factors. For example, improving the Inuit employment situation is not possible without also improving the quality of training programs and the educational system.

Secondly, any in-depth analysis of either unemployment, training, or education must deal with the Inuit cultural realities. Any attempt at remedying current problems in isolation of the Inuit cultural context, will at best provide only limited, short term solutions.» (1985, p. 1).

Ces deux éléments sont très importants car ils représentent l'essence de toute amélioration de la situation de l'emploi. Le premier point, pour être efficace, doit être basé à long terme afin de pouvoir modifier l'ensemble des éléments de l'éducation, de la formation et de l'emploi. De plus, sa réalisation ne sera possible que si des sommes considérables y sont consacrées lesquelles ne sont disponibles qu'avec la participation des gouvernements.

Par contre le second point, traitant du respect de la culture, est de nature inuit et le manque d'attention qui y a été porté jusqu'à présent est problablement dans le passé la cause principale de l'échec des initiatives gouvernementales.

Donc, pour être efficace tout développement de stratégie de l'emploi doit être basé sur une meilleure collaboration entre les gouvernements et les Inuit. Cependant ces derniers ne veulent plus avoir seulement un rôle de consultation, ils veulent être partenaires à part entière dans le processus de développement et d'implantation des programmes.

De la théorie à la pratique

Tous ces documents et pourparlers sont bien intéressants et il ne fait aucun doute que d'importantes améliorations ont été réalisées depuis une dizaine d'années. Le groupe de travail est un élément très encourageant et laisse présager de meilleures actions pour l'avenir. Déjà, le programme «Northern Careers» et l'Arctic College sont des preuves de bonne volonté des gouvernements fédéral et territorial.

Cependant, le nombre d'Inuit qui complètent ces programmes est très limité. Ce qu'il faut c'est une politique d'ensemble basée sur la collaboration des Inuit et des gouvernements dans une perspective à long terme.

Bien que possible en théorie, la mise en pratique de ces belles promesses est une autre histoire. Le pays étant dans une période de restrictions budgétaires, les gouvernements accepteront-ils de verser des fonds additionnels pour la réalisation d'un tel programme?

Si les gouvernements semblent enclins à negocier, la récente coupure budgétaire réduisant de 40% les fonds alloués à la formation dans les T.N.O. (Report of the Task Force, 1986) rend douteuse leur volonté de passer à l'action. Ainsi au moment où les organisations inuit ont besoin de fonds supplémentaires pour réaliser leurs objectifs de formation de personnel, près de la moitié de leur budget disparaît.

De plus, au Canada il est rare que l'on planifie à long terme. Habituellement les gouvernements cherchent davantage à satisfaire les besoins immédiats qui donnent des résultats rapidement. Mais une telle attitude ne peut que donner des résultats partiels dans le contexte nordique.

Conclusion

Que réserve l'avenir pour ce qui est de l'amélioration de la situation de l'emploi dans le domaine de la gestion par les Inuit dans les T.N.O.?

Cela est bien difficile à prédire, probablement que tant qu'il n'y aura pas un véritable dialogue «Nord-Sud» sur la question avec un réel désir d'y apporter des solutions, la situation demeurera sensiblement la même.

Comme le mentionne Mike Bell: «The decision making power remains in the hands of the Kadlunas, not because Inuit people are excluded from these positions but because they lack the education and technical competence to acquire them. As a government we have been very successful at hiring Inuit people but not very successful at training them.» (Jan. 1983, p. 38).

L'éducation est donc un élément clé qu'il est essentiel de réviser afin que le système corresponde davantage à la culture inuit. Enfin, s'il pouvait être possible de concevoir la différence culturelle comme un «avantage» plutôt qu'un «problème», il serait sûrement possible de réaliser des progrès réels. Cela demanderait des dispositions différentes de celles qui existent à present mais ce serait plus enrichissant tant pour les Inuit que pour le reste du Canada.

Si les Inuit étaient moins dépendants des gouvernements, ils pourraient davantage conserver leur fierté et développer la région selon leurs aspirations. Pour les gouvernements, cela représenterait des dépenses moindres et pour l'ensemble des citoyens, une région agréable à visiter.

Réalité ou utopie? Sait-on jamais, beaucoup de changements se sont déroulés dans le nord depuis les deux dernières décennies. Peut-être qu'une position ferme des organismes inuit pourra faire la différence, mais le temps presse et le fossé s'agrandit; espérons qu'un pont pourra être construit avant que les rives ne se soient trop éloignées l'une de l'autre.

Références

Bell, M., 1985. A Northern Perspective on Social Caring: The Role of Local Residents. Talk to the N.W.T. Mental Health Association, 13th Annual General Meeting. 17 p.

_____ June 1983. A Management Strategy. Social Services in the Baffin Region, N.W.T. 31 p.

_____ January 1983. Social Services in the Baffin Region, N.W.T.: are we into the provision of services or the development of people? A Discussion Paper. 40 p.

Inuit Tapirisat of Canada, 1985. A Brief Prepared for Submission to the Legislative Committee on Bill C-62. 12 p.

Jacobs, P., 1981. Population, Ressources et Environnement. Étape de la consultation publique: Étude régionale du détroit de Lancaster. Ministère des Affaires Indiennes et du Nord, Ottawa. 69 p.

Nunasi Corporation, 1985. Nunasi Careers Program. Ottawa: Nortext Information Design Limited. 29 p.

Nunasi Corporation, January 1986. Nunasi Report. Volume 3, no. 1. 20 p.

Rapport du Groupe d'Études, 1986. Meilleure Éxécution des Programmes: Indiens et Autochtones. Nielsen Task Force, MASC.

Rapport du Comité Parlementaire, 1985. «L'équité en matière d'emploi.» Chapitre 13: Égalité pour tous. J.P. Boyer, Député président. pp. 111-147.

Report of the Task Force on Inuit Management Development, 1986. A Strategy for Inuit Management Development.

Robitaille N. et Choinière R., 1984. Aperçu de la situation démographique et socio-économique des Inuit du Canada. Département de Démographie, Université de Montréal, pour le Ministère des Affaires Indiennes et du Nord. 116 p.

Stiles M. and Associates, 1984. Nunavut Aulatsininga. An Action Proposal for an Inuit Management Development and Training Strategy in Preparation for Nunavut and a Lands Claims Settlement. Prepared for I.T.C. 52 p.

SPOUSAL ASSAULT AMONGST THE DENE: AN HISTORICAL PERSPECTIVE ON A PRESENT-DAY PROBLEM

Shirley M. McGrath

Faculty of Administration, University of New Brunswick, Fredericton, New Brunswick E3B 5A3

Level: Bachelor's

Abstract

Spousal assault, or wife battering, is a serious problem throughout North American society today. Nowhere, however, is it more so than in Northern Canada where, it is estimated, one woman in four is beaten by her husband or partner. This paper focusses on the present extent of the problem of spousal assault amongst the Dene, in the light of an historical perspective, in order to explore those factors which may contribute to a high incidence of violence in the relationships between Dene men and women.

Key words: Spousal assault, wife battering, Dene.

Résumé

Les violences conjugales constituent un grave problème dans toute la société nord-américaine actuelle. Cependant, la brutalité maritale est particulièrement fréquente dans le Nord canadien, et l'on estime qu'une femme sur quatre est battue par son mari ou son concubin. L'étude porte sur l'envergure actuelle de la brutalité maritale chez les Dénés, à partir d'une perspective historique, afin de mettre en évidence les facteurs qui pourraient contribuer à la violence fréquente des relations entre hommes et femmes chez les Dénés.

Mots-clés: Violences conjugales, brutalité maritale, Dénés.

Introduction

On September 3 of 1985, the Member of Parliament for the Western Arctic pleaded guilty to the charge of spousal assault (Doug Holmes, *News/North*, 6 September 1985:A1). Three weeks later, the MLA for Deh Cho pleaded guilty to the same charge (*News/North*, 4 October 1985:A1). On November 11, the mutilated body of a woman was found in a ditch just outside Yellowknife (*News/North*, 20 Nov. 1985:A1). These three victims of violence in less than six months had several things in common: all were women, all lived in the Western Arctic region of the Northwest Territories. And all were of the Dene people.

Violence against women, particularly domestic violence, has received increasingly widespread attention in recent years as women's groups gain support for the position that wife battering is not just "a family affair", but a crime against society and should be dealt with as such (e.g. MacLeod, 1980:35, 42). It is estimated that one woman in ten in Canada is regularly beaten by her husband or partner (Ibid., 1980:21). But this figure is much higher in the North: "closer to one in four", according to the Department of Information of the Government of the Northwest Territories (October 1985:2). This has very serious implications for Natives (Dene and Inuit), who represent over half the population of the Northwest Territories.

This paper focusses on the present extent of the problem of spousal assault amongst the Dene from an historical perspective in order to explore those factors which, by their presence or absence, may contribute to a high incidence of violence in the relationships between Dene men and women.

The term "spousal assault" (rather than the more common "wife battering" or "wife abuse") is generally used throughout to include violence by a woman against her husband, except where the victim is explicitly female. Although far less frequent, husband beating is not an unknown occurrence: in one of every six domestic dispute calls to the RCMP in Yellowknife, the batterer is female (LuAnn Lovlin, *Yellowknifer*, 2 October 1985:A7). Violence between couples who may be living together but are not married is included as well.

Contributing factors

A review of published material relating to spousal assault amongst the Dene suggests several recurring themes which may be described as factors contributing to the problem. Some of these (such as the introduction of alcohol and cultural disorientation) may be directly attributed to White influence; others (religion and marriage) have been considerably altered through White contact, but still retain underlying elements of traditional Dene values and beliefs. A third category (childhood influences, character and disposition, and community attitudes) may be considered inherent in Dene society. Each of these variables is examined in the context of both the past and the present, and related to its probable impact on the problem of spousal assault.

Alcohol

Alcohol is by far the most frequently mentioned factor in relation to spousal assault amongst the Dene in both historical and contemporary accounts. Poirier and Mitchell (1985:2) describe the "destructive dependency on alcohol" on the lives of Native people, and its often violent outcome. Alcohol was a factor in the Gargan spousal assault case, and Gargan was berated by Ms. Pool in a *News/North* editorial (4 October 1985:A2), not for his crime, but that he, a leader who is an active opponent of alcohol abuse, was intoxicated at the time.

According to one submission to the Task Force on Spousal Assault (1985:Appendix 3, p. 4), the R.C.M.P. report alcohol abuse in almost 99 percent of all domestic violence situations in the North. Usually the man is drunk, but the woman's chances of being severely beaten are increased if she is too.

Savishinsky (1970) describes incidences of wife beating as a result of repressed hostilities, anger and frustration that surface when drunk, especially among younger couples.

Durgin (1976) also makes reference to drinking disputes, and Hara (1976) maintains that aggression is very rare if sober. Honigmann (1949:156) too found that certain men are "noted for aggression toward their wives when intoxicated".

The impression given by these accounts is that spousal assault amongst the Dene was far less frequent and severe before alcohol was introduced. The Task Force findings (1985:53) support this: "Elders in communities have said that the brutal assaults they witness did not occur before alcohol was introduced into the communities."

Some communities, in an attempt to cope with the problems associated with alcohol abuse, restrict the use of liquor and are designated as 'dry'. However, the Task Force (1985:53–54) discovered that, while spousal assault is less frequently reported in such communities, this does not imply that spousal assault does not occur, but rather that reporting of violence is inhibited by the fear of discovery of illegal transportation or brewing of alcohol. Nor does removing alcohol from the community solve the problem, as *Spousal Assault Network* (1985:15) points out: "Even during sobriety, the aggressiveness is still there." Although not a direct cause of spousal assault, alcohol nonetheless does present a serious problem insofar as it is a facilitator and a socially acceptable "tool to justify violent actions" (MacLeod, 1980:22).

Cultural disorientation

Savishinsky (1970) appears to have touched upon a key factor with respect to spousal assault amongst the Dene in his term "cultural disorientation", which he uses to explain the repressed hostilities, anger and frustration that so often result in wife beating among the younger couples. These feelings are not only taken out on the women, but on dogs as well. Poirier and Mitchell (1985:2) describe the source of this problem, which applies to native people in the North in general, but most especially to the younger generations:

> The conflict begins when the people are unable to deal with rapid change, especially in the far north . . . The abuse of an entire way of life, new patterns of living and religious beliefs over the years have left native people in a state of confusion and led to the desperate situations that exist today . . . Violence becomes the expression of anger, frustration and hurt that soon touches all aspects of a person's life and that of the people closest to them in the family.

Phoebe Nahanni (1977:21) speaks of the ancient Dene way of life, an economy based on hunting, fishing and trapping, as still happening today. While this may be true to a limited extent, such as at the Willow Lake community described by Robert Janes (1983), the effects of modern civilization are impossible to escape completely: modern technology and the mass media are everywhere. Nor is it feasible for the Dene to make a gradual transition into the twentieth century: Model T Fords are now collectors' items, vacuum-tube computers are no longer available, and resource exploitation by multinational corporations cannot be halted. And so the Dene are caught in transition between their traditional lifestyle, no longer viable as their sole means of survival, and that of modern "Southern" society; it is hardly surprising that the result is confusion, frustration, anger. And violence.

Religion

Before the influx of Catholic (and later Anglican) missionaries to the Northwest Territories in the mid-nineteenth century (Fumoleau, 1973:322 ff.), the Dene had no organized religion as such. As Hill-Tout (1907:167) reports, "They recognized no Supreme Being who controlled the universe, no High Gods who ruled the destinies of men, not even a 'Great Spirit' . . . to whom they could pray for protection and help." According to Gaultieri (1984:122), many missionaries found this "astonishing and perplexing." This is not to say, however, that the Dene did not have a spiritual life: rather, they simply believed in a "power" that was inherent in the universe (Helm, 1976:42), or "a multiplicity of spirits, that all nature, in all her forms, was thus animated" (Hill-Tout, 1907:166).

Duchaussois believed that the introduction of Christianity was unequivocably to the benefit of Dene women: before the arrival of the missionaries, he claims, "Woman was a slave: beaten, exchanged, lent, sold, cast off, mutilated, killed, as men might choose" (1923:33), and "Mary Immaculate, preached by the Catholic Church, raised poor pagan woman from her low estate" (1923:34).

Father Duchaussois may have sadly misjudged the impact of Christianity, however. As Helm says (1976:22), "the major histories of missionary activity in the Subarctic . . . suffer from a surfeit of sectarian self-praise", and Gaultieri (1984:117–118) found that "For the most part the missionaries regret the pattern of the last one hundred years . . . they wish that some of that work could be undone".

One regrettable "Christian" attitude is that pertaining to wife-beating, which was openly encouraged in the Middle Ages (MacLeod, 1980:27); this attitude still prevails to a large extent today. In a letter to the Task Force on Spousal Assault (1985:Appendix 5), the Reverend James Bell defends the views of the Bible on women; clearly this would not be necessary were it not possible (and more common) to use the Bible to support the opposite view, that it is a man's "Christian duty" to control his wife. In his ministry in the Arctic, Bell has found that such attitudes are "all too common and widely accepted as legitimate" and has "come across men who firmly believe they have a God given duty to subjugate their wives and whenever necessary, use violence as a means to bring about that subjugation."

Duchaussois' "poor pagan woman" (op. cit.) certainly cannot be said to have noticeably benefited from Christianity with regard to battering: it is, if anything, one more excuse for her husband to beat her.

Marriage and sexual mores

One situation which often leads to spousal assault is that of marital infidelity. Durgin (1975) notes that violence between a Dene husband and wife may result from disputes over extramarital sexual affairs; this is acceptable behavior, according to Honigmann (1949:156): "a man feels entitled to beat his wife if he suspects she has been untrue." He goes on to say, however, that not all men avail themselves of this permitted behavior.

But although sexual fidelity in marriage is a cultural norm amongst the Dene, both historically and at present, the institution of marriage has changed considerably. The

Native Women's Association booklet *Does Your Husband or Boyfriend Beat You?* (1984) describes the lengthy, complicated legal route a person must now go through in order to obtain a divorce under Canadian law; more difficult still if, as is the case for many Dene women, that person has very little in the way of financial resources and does not speak the language of the judicial system (i.e. English or French). Previously, however, marriage was "a very informal and simple affair" (Hill-Tout, 1907:181–182), easily entered into and easily terminated. A man could secure a wife by purchase among the western Nahane, and all tribes practised polygamy.

Furthermore, Hill-Tout relates (1907:157), "If one man desired another's wife, all he has to do to secure her is to challenge her husband to a public wrestling match . . . and get the better of him in the match." Morice (1931–249) explains:

> There was nothing bloody or even dangerous in the encounter. It meant simply a wrestling contest. Fair play was to be observed, and though the struggle was public, nobody would have dreamt of interfering . . . Of course, the winner took the prize, that is, the young woman, and possessed it until he was himself beaten in a subsequent contest.

Under such circumstances, with marriage being treated so casually and there being neither any great difficulty nor stigma attached to getting a divorce, it would be expected that the likelihood of marital infidelity would be significantly reduced and so also the spousal assault which now so often ensues.

Childhood influence

Childhood in any society is a time of learning, a time when lasting impressions are formed and the world as it is observed is accepted without question as the way it should be. It is widely recognized that many batterers come from violent homes, as do many victims (e.g. MacLeod, 1980:14, 25) and, as the Task Force notes (1985:4), "The lessons this violence teaches ensures that the legacies of violence are passed on and will be endured and suffered in our children's and grandchildren's generations."

But while the effects of learning violence in the home are deplorable for any child, they are far more so for a Dene child: children, in the Dene tradition, learn by doing from adult example. In his study of a Dene (Slavey) group following a traditional lifestyle of hunting, trapping and fishing for six months of the year at Willow Lake, Robert Janes found that children were involved in adult activities to such an extent that they themselves were archaeologically invisible: "Dene children learn by doing. . . . Observation, imitation, and trial-and-error are the ways in which Dene children develop the knowledge and skills which are essential for life in the bush" (1983:74).

This treatment of their children by the Dene as, in essence, "small adults" is perhaps related to more generalized beliefs and attitudes concerning children. The custom of "giving away" a child is not uncommon (one of every pair of twins is always given to another family) and, although this practice may be very frustrating to government authorities, the Dene find nothing wrong with it. One explanation which has been given is that the spirit of a recently deceased ancestor may be in need of the infant's body in which to reside. In one such recent instance in the village of Detah (C. Babicki, Yellowknife, July 1984), an illegitimate child was given to the mother's sister as a most welcome wedding gift, and the mother continued to nurse and care for it in her sister's home.

The belief, therefore, that an ancestor's spirit resides in a child is one possible explanation for the treatment of children as adults; another, of course, may be simple economic necessity and efficiency if this were at one time the best way to ensure that children contributed to the welfare of their community as early as possible. But the attitude of the Dene towards their children appears to be related to yet another unhappy consequence of the spousal assault problem: while in non-native society a woman who is beaten normally becomes very protective towards her children, the author was told by a member of the Task Force on Spousal Assault (Yellowknife, July 1985), native children in such situations often suffer abuse by the mother. Green (1983:39) also estimates that "child abuse is a factor in many cases" handled by the Native Courtworkers' Association.

Spousal assault amongst the Dene, then, has two implications for children: first, that because of the very strong tradition of learning from adult example, these children will perceive battering as normal and acceptable behavior and in turn become batterers or victims; and second, the abuse of their children by either parent as a side effect of spousal assault. As one woman in a Mackenzie Valley community said, "When I get beaten up, the children see it too and try to stop him, then he starts beating them up or chases them out in the middle of the night in the middle of the winter" (*Spousal Assault Network*, October 1985:10).

Character and Disposition

It is difficult to conceive of the mild-mannered, timid Dene deliberately and consciously taking the role of aggressor. But according to Bonnie McFarlane, an assertiveness training instructor and researcher on wife abuse, people who are non-assertive most of the time will very often express their frustrations and anger through physical aggressiveness, and will usually choose a "safe target", i.e. one who does not have power over them and is not likely to fight back (Fredericton, Nov. 1985) An anonymous native woman describes her husband in a poem in *Spousal Assault Network* (October 1985:8):

> I remember as he was growing up
> the other kids used to pick on him
> I guess he's still hurting
> from his childhood.

But weakness, victimization and aggression are not characteristics that can be ascribed only to an individual. The Dene people as a whole feel that they are oppressed and victimized by White society, as is very evident in their submissions to the Berger Inquiry (*Dene Nation, the Colony Within*, 1977). Phillip Blake (1977:6–7) refers to the school in which the inquiry is taking place as "a symbol of white domination and control . . . . part of a system set up to destroy Indian culture and to destroy our pride in our Indian heritage" and pleads, "Please do not destroy us." Frank T'Seleie (1977:16) cries, "you are stealing my soul, my spirit. By scheming to torture my land you are torturing me." And George Erasmus, President of the Indian Brotherhood of the

Northwest Territories, simply states, "With the coming of the Europeans, our experience as a people changed. We experienced relationships in which we were made to feel inferior. We were treated as incompetent to make decisions for ourselves." (1977:178).

But what were the Dene like before their lands and their way of life were seriously threatened by White government and White settlers? Hill-Tout (1907) refers to their timidity as characteristic, but Morice (1931:111) gives a fuller picture:

> Meekness and cruelty are two moral attributes which seem to exclude one another. Yet it is incontestable that they are to be found side by side in the same Dene tribes . . . . peaceful and meek as these northern congeners undoubtedly are when in their normal condition, they are not any less cruel when provoked, or even with the weak without provocation, or again when they can take unfriendly people at a disadvantage.
>
> I could expatiate on their lack of humanity to their own wives, who had formerly to do all the hard work, even to the dragging of their heavily loaded toboggans on the very day that they had been delivered of a child. I could enlarge on the unspeakable indignities and harsh treatment some of their tribes meted out to their widows and the lack of feeling or consideration they all display towards the old and orphans. I could adduce as examples of their cruelty the numerous massacres in which they were the prime actors.

In fact, aggression against those weaker than themselves does not appear to be a recently-developed Dene trait by any means. Even in the early 1700's, according to June Helm (1971) as cited by Rene Fumoleau (1973:319), "Beaver and Yellowknives — obtained firearms and turned to fur raiding and generally bullying of their defenseless Athapascan neighbours, and when possible, of each other."

Attitude of community

The attitude of the community can play an important role in an abusive relationship: depending upon whether the violence is condoned, condemned, or simply ignored, a different kind of pressure will be placed on the couple. Poirier and Mitchell (1985:23) touch on this subject as it applies to northern native communities in general where, they note, "the community and family have a strong influence on the defining and handling of unacceptable behavior", and suggest that these existing systems must be taken into account when implementing the Canadian Justice System in these areas.

One such instance of "community justice" has been told (Yellowknife, June 1985) of a native woman who was regularly and brutally beaten by her husband over a number of years. Finally one night, it was said, she smothered him in his sleep and disposed of the body. The community were all aware of what had happened, but when an official inquiry was instigated, everyone denied any knowledge of the event; eventually the investigation had to be dropped because of lack of evidence, but the community felt that justice had been done.

Community support to victims of spousal assault would be much more effective, however, if abuse was actually prevented or stopped (in a manner less drastic than murder). But to do so requires costly facilities, such as transition houses, and professionals, such as counsellors. According to the G.N.W.T. *Spousal Assault Network* (October 1985:2), there are "NO transition houses or counselling programs for battered women in the NWT and NO therapy for violent men", although Begalki reports in the *News/North* (4 October 1985:B5) that a few communities do have crisis shelters.

Close community ties but lack of support can be very strong conflicting forces to a battered Dene woman. Her life-long ties to the community prevent her from leaving (Green, 1983:33), but also hinder her in pressing charges. As Crown Attorney John Shipley related to Susan Green (1983:84),

> the victims often display a great reluctance to pursue their complaints once the matter has reached the courts . . . . As the significance of the conduct recedes with the expiration of time, the reconciliation process and in many cases continued intimidation of the victim by the accused, the willingness to testify evaporates. While this problem exists in the South, it is clearly exacerbated by familial and community pressures and the cultural xenophobia of the smaller communities of the Northwest Territories.

There is also evidence of this ambivalence on the part of the community as a whole in the past. Honigmann (1949:266) notes that the Dene felt that hostilely-disposed people, while not admired, must not be offended; and that such people were best locked up or removed. The Task Force on Spousal Assault (1985:8–9) similarly found:

> Native people across the north told us that although it was far less frequent than in modern times, spousal assault did take place in their cultures in the past. Some instances, apparently motivated by perceived need to chastise a lazy mate, were condoned to the extent that they did not give rise to action by the group or community. Others, perhaps because the beatings were more severe or administered more openly for less acceptable reasons, caused both criticism and group action.
>
> Spousal assault was not encouraged and under some circumstances, the offender was severely disciplined and sometimes threatened with banishment . . . . in native society, people are much less openly critical of one another and much less likely to intervene.

Community attitudes are effectively summed up by one Dene woman when she says, "The community don't understand the problem, because how many times I was beaten up and everyone would say why I reported on him [sic] and were disgusted with me" (*Spousal Assault Network*, October 1985:10).

Conclusion

Spousal assault amongst the Dene is a problem with many facets: there is no single cause, and there are many facilitating agents as well. The timid, non-assertive disposition of the Dene people, coupled with the manner in which they have been plunged into an alien culture through no choice of their

own, leaves them with few outlets for anger and frustration, other than violence against a weaker mate. The situation is further complicated by new mores regulating marital behavior and divorce procedures, aggravated by alcohol abuse, and confused by the introduction of Christianity and its interpretation. By not actively opposing spousal assault, the community implicitly condones it; and children of each succeeding generation learn from their parents that violence is acceptable behavior. Thus a problem which was once relatively insignificant has grown in both magnitude and complexity to the degree where it now affects not a few individuals, families, or even communities, but the Dene as a whole.

References

Anon. "Gargan convincted of spousal assault". News/North, 4 Oct. 1985, p. A1.

_____. "Police seek clues in Detah woman's death." News/North, 20 Nov. 1985, p. A1.

Begalki, N. "Yellowknife YWCA seeks funds for house." News/North, 4 Oct. 1985, p. B5.

Bell, J. "Battered women and the bible, subjection or partnership?" Report by the Task Force on Spousal Assault. Northwest Territories. Yellowknife: Minister Responsible for the Status of Women, 1985, Appendix 5.

Blake, P. "Statements to the Mackenzie Valley Pipeline Inquiry." Dene Nation, the Colony Within. Ed. Mel Watkins. Toronto: University of Toronto Press, 1977.

Christian, J. The Individual in Northern Dene Thought and Communication: a Study in Sharing and Diversity. Ottawa: National Museums of Canada, 1977.

Duchaussois, P. Mid Snow and Ice: The Apostles of the North-West. London: Burns Oates & Washburn, 1923.

Durgin, E.C. Brewing and Boozing: A Study of Drinking Patterns Among the Hare Indians. Ann Arbor: University Microfilms, 1975.

Erasmus, G. "We the Dene." Dene Nation, the Colony Within. Ed. Mel Watkins. Toronto: University of Toronto Press, 1977.

Fumoleau, R. As Long As This Land Shall Last. Toronto: McClelland and Stewart, 1973.

Green, S.L. An Analysis of Victims' Needs in the NWT: Victims' Needs Assessment Study. Yellowknife: Departments of Justice, Government of the Northwest Territories and Government of Canada, 1983.

Gualtieri, A.R. Christianity and Native Traditions: Indigenization and Syncretism among the Inuit and Dene of the Western Arctic. Indiana: Cross Cultural Publications, 1984.

Hara, H.S. Hare Indians and Their World. Ann Arbor: University Microfilms, 1967.

Helm, J. The Indians of the Subarctic: A Critical Bibliography. Bloomington: Indiana University Press, 1976.

_____ et al. "The contact history of the Subarctic Athapaskans: An over view." As Long As This Land Shall Last. Rene Fumoleau. Toronto: McClelland and Stewart, 1973.

Hill-Tout, C. British North America: I. The Far West, the Home of the Salish and Dene. Toronto: Copp Clark, 1907.

Holmes, D. "NDP wants Nickerson out." News/North, 6 Sept. 1985, p. A1.

Honigmann, J.J. Culture and Ethos of Kaska Society. New Haven: Yale University Press, 1949.

Janes, R.R. Archaeological Ethnography Among Mackenzie Basin Dene, Canada. Calgary: Arctic Institute of North America, 1983.

Lovlin, L.A. "Facilities for victims overloaded." Yellowknifer, 2 Oct. 1985, p. A7.

MacLeod, L. Wife Battering in Canada: The Vicious Circle. Hull: Canadian Government Publishing Centre, 1980.

Morice, A.G. The Great Dene Race. Vienna: Press of the Mechitharistes, 1931.

Nahanni, P. "The mapping project." Dene Nation, the Colony Within. Ed. Mel Watkins. Toronto: University of Toronto Press, 1977.

Native Women's Association of the NWT. Does Your Husband or Boyfriend Beat You? Yellowknife, 1984.

Northwest Territories. Department of Information. Spousal Assault Network. Yellowknife, October 1985.

Northwest Territories. Task Force on Spousal Assault. Report by the Task Force on Spousal Assault. Yellowknife: Minister Responsible for the Status of Women, 1985.

Poirier, J. and A. Mitchell. Native Women's Circle: A Right to Freedom and Respect. Montreal: Native Para-Judicial Services of Quebec, 1985.

Pool, A. "Leaders should not be seen as drunks." News/North, 4 Oct. 1985, p. A4.

Savishinsky, J.S. Stress and Mobility in an Arctic Community: the Hare Indians of Colville Lake, Northwest Territories. Ann Arbor: University Microfilms, 1970.

T'Seleie, F. "Statements to the Mackenzie Valley Pipeline Inquiry." Dene Nation, the Colony Within. Ed. M. Watkins. Toronto: University of Toronto Press, 1977.

Watkins, Mel. Dene Nation, the Colony Within. Toronto: University of Toronto Press, 1977.

ATTITUDES ABOUT SUSTAINABLE DEVELOPMENT IN YUKON

David McRobert

Faculty of Environmental Studes and Osgoode Hall Law School, York University, North York, Ontario M3J 1P3

Level: Master's

Abstract

In June 1986 the Yukon Territorial Government (YTG) released a draft discussion paper on prospects for a more sustainable economic development policy entitled *Yukon 2000*. The ideas in that document and several other recent initiatives in the areas of renewable resource management and import substitution provided the inspiration for this research.

The aim of the study was to determine whether these recent policy initiatives were understood and supported by Yukoners. A questionnaire was designed and thirty policy-makers, opinion-formers and "stakeholders" in government, industry, the native community and environmental groups were interviewed in July and August of 1986. This paper surveys some of the preliminary results obtained in the study.

The results suggest that respondents believe that Yukoners support measures such as import substitution. In addition, most of those interviewed believe that a slower pace of both economic development and population growth is preferable because this would allow Yukoners to maintain greater control over key decision-making processes and reduce the impact of the boom and bust cycle. However, it was also

clear that a wide discrepancy existed over the interpretation of certain key aspects of the YTG initiatives and this, in turn, indicates that the YTG should increase public education activities to inform Yukoners about the different policy options related to the *Yukon 2000* project specifically and sustainable development in more general terms.

Key words: Attitudes, conservation, economic development, Innis, import substitution, population growth, Yukon.

Résumé

En juin 1986, le gouvernement du Territoire du Yukon a publié la version préliminaire d'un document de travail intitulé *Yukon 2000*, au sujet des éléments d'une politique de développement économique plus régulier. L'auteur s'est inspiré, pour faire ses recherches, des idées directrices de ce document et de plusieurs mesures récentes du gouvernement en matière de gestion des ressources renouvelables et de remplacement des produits d'importation.

Il s'est efforcé de déterminer si ces mesures prises récemment sont bien comprises par les Yukonais, et si ceux-ci les soutiennent. L'auteur a élaboré un questionnaire et a interrogé environ trente responsables de l'Administration, de l'industrie et des collectivités autochtones au cours de juillet et d'août 1986. Dans sa communication, il passe en revue certains des résultats préliminaires de cette enquête. Ils indiquent que la population yukonaise soutient largement des mesures telles que le remplacement des produits importés. En outre, la plupart des personnes interrogées croient que le développement économique et la croissance démographique devraient progresser selon un rythme moins rapide, permettant aux Yukonais de garder la haute main sur les principaux processus décisionnels et de limiter les effets fâcheux des alternances de prospérité et de marasme économique. Cependant, l'auteur conclut aussi qu'il existe de grandes divergences d'interprétation de certains aspects des mesures cruciales prises par le gouvernement, et donc que celui-ci devrait s'efforcer de sensibiliser le public au sujet des différentes options décisionnelles envisagées pour le projet *Yukon 2000* en particulier, et pour un développement économique régulier en général.

Mots-clés: Yukon, développement économique, remplacement des produits importés, conservation, Innis, croissance démographique.

Introduction

The issue of frontier resource development has preoccupied economic and political theorists in Canada for several decades (Page 1986). Prominent among the contributors to the debate on the issue has been Harold Adams Innis, the political economist who traced the history of staples development in the fur industry and the cod fisheries in the 1920s and 1930s. Innis was concerned about Canada's dependency on other industrial economies for capital, technology and markets. In his view, this dependency entrenched regional disparity in the Canadian economic fabric and promoted a branch-plant mentality (Innis 1956; Page 1986).

Innis acknowledged that this perception of development had been shaped, in part, by what he termed the "economic cyclone" of the Klondike (Innis 1930 cited in Page 1986: 50). For this reason, it should not be surprising that his views continue to influence scholars interested in major development projects and current policy initiatives in Yukon and the Northwest Territories. Innis' approach to political economy has a great deal to offer to theorists interested in the past and future development of Canada's northern territories (McRobert 1984; Watkins 1977; Usher 1981).

In view of the critique of staples development offered by Innis, one of the prescriptions that seems to arise from his thought is the need for more sustainable development. To this extent, considerable convergence is evident between Innis' economic nationalism and more recent critiques of market economics offered by environmental theorists (see, for example, Daly 1980). Like Innis, advocates of the "conserver society" reject the vulnerability and social dislocation caused by staples development. As an alternative, they advocate movement towards local control of production for local needs (Robinson and Ghostkeeper 1986; Schrecker 1983; Valaskakis *et al.* 1979). In the leading policy statement on conservation and development, this idea has been termed as sustainable development (International Union for the Conservation of Nature 1980).

Just what this cryptic term means is open to debate, as I have argued elsewhere (McRobert 1986). Moreover, it is unclear as to what it could mean in a northern context because it seems unlikely that northerners will be able to completely disavow their historical connection to staples production in the near future. Nevertheless, the prospect for alternative economic development and greater self-sufficiency based on these concepts is gaining legitimacy in many parts of the north. Underlying this shift are attitudes which support increasing local control over development, as the analysis below shows.

Accordingly, it is argued herein that sustainable development is a northern variation on the theme of self-sufficiency popularized by economists such as Fritz Schumacher in the 1970s. In *Small is Beautiful* Schumacher (1973:34) characterizes self-sufficient development in terms of decentralization, growth to planned objectives and environmental protection. Similarly, Herman Daly (1980) identifies self-sufficient economies as those which rely primarily on renewable resources and attempt to balance materials input and output through measures like recycling and energy conservation.

Another aspect of self-sufficiency is reduction of reliance on goods produced elsewhere through import substitution. Schumacher (1973:34) describes this policy as "production from local resources for local needs."

Over the past few months, Yukon Territorial Government (YTG) has begun to promote these concepts of self-reliance in their search for a more coherent long-term economic development strategy. Accordingly, it could be argued that the YTG is at the leading edge of environmental and social policy-making in Canada today and their approach could serve as a model for other governments in Canada and the rest of the world.

The key element in this push to devise a new economic development strategy is a discussion paper entitled *Yukon 2000: Building The Future*. A draft of it was released in spring 1986 and subsequently was the subject of a conference in Faro at the end of June. After a rewriting during the following summer, the paper was published and distributed throughout the Territory. It also was the subject of hearings

undertaken in the Fall and Winter of 1987. In brief, *Yukon 2000* outlines some of the options available to Yukoners over the next decade and contends that economic development should be guided by principles such as import substitution, equality of opportunity and renewable resource development (YTG 1986a).

Other recent initiatives of the Department of Renewable Resources also suggest a commitment to sustainable economic development. In December 1985 the Department released a discussion paper on renewable resource management (YTG 1985b) which acknowledges that environmental protection and economic development should be promoted simultaneously. In addition, the YTG has responded positively to the World Conservation Strategy (WCS). This document, which was produced in 1980 by the United Nations Environment Program and the International Union for the Conservation of Nature (IUCN), was the inspiration for a federal Task Force on Northern Conservation established in 1984 by the federal Minister of Indian and Northern Affairs, the Hon. John Munro (Task Force on Northern Conservation 1984). The Task Force recognized the need to integrate conservation and development in economic planning, contending that parks, mining and other land use activities can co-exist if proper planning is undertaken. Based on the policies expressed by the YTG to date, it appears that the spirit of this recommendation has been adopted.

The Task Force also asserted that an important aspect of sustainable economic development policy is preservation of major areas in a relatively pristine form. In addition, current knowledge about renewable resource management and land use planning in Yukon would also seem to confirm that sustainable development must entail conservation programs which will set aside for the future large areas for parks and wilderness reserves (Theberge *et al.* 1980). In passing it is noteworthy that the federal government announced the creation of the northern Yukon National Park in July 1984.

Finally it should be pointed out that the Department of Renewable Resources of the YTG prepared one of the most innovative studies on the WCS to date last spring. The study, of Old Crow in the northern Yukon, shows that renewable resources such as caribou, fish, and wood continue to meet most of the basic needs of residents. Moreover, although there are numerous potential difficulties to overcome to ensure a sustainable future for the community, the study maintains these can be overcome through planning and management at the local level (Fuller and McTiernan 1987).

With these initiatives in the background, two students, the author and Chris Smit, an undergraduate at Ryerson, decided it would be interesting to examine the attitudes of Yukoners towards self-sufficiency during the summer of 1986. The goals were to examine the new attitudes about economic development and population growth that motivated these initiatives and to test the hypothesis in *Yukon 2000* that the time is right to build a new consensus on economic development in the territory.

The economic history of Yukon: an overview

Before setting out the hypotheses and method that guided our study, the recent economic history in Yukon must be reviewed.

The present economic situation in Yukon stems from a steady progression of staple exploitation which began with fur trading and eventually led to whaling based on Herschel Island in the late nineteenth century (McCandless 1985). These activities were modest in their impact compared with the first major intrusion into the Territory by metropolitan forces during the Gold Rush in the late 1890s (Zaslow 1971). It was a dynamic period in Canadian history and one might wonder what kind of ruckus modern environmentalists would raise if a similar kind of development scheme was proposed today. However, while it was exciting, this frenzied outburst could hardly be termed sustainable.

Since this initial period, primary resource extraction has remained the foundation of the Yukon economy (Rea 1968; Hamelin 1979). Throughout the early part of this century, the fur industry and mining continued to flourish. There were shifts to silver, zinc, copper, asbestos and other metals in the mining sector and the prices for furs varied but the overall pattern has been fairly consistent; staples development has dominated the economy.

Undoubtedly the present desire on the part of many residents to move Yukon's economy towards sustainability has roots in this pattern of dependency on outside markets. But in Yukon today it is probably most clearly traced to the boom and bust fluctuations of 1970s and the early 1980s. Possible pipeline construction through the territory to southern markets stimulated an economic boom of significant impact in the 1970s. However, another crucial event which stimulated the emergence of an embryonic consensus about future economic development was the closure of seven major mines, including Faro, in 1982.

The experience of 1982 had a devastating impact on many businesses in Yukon and once again confirmed the argument made above that staples economies are vulnerable to outside influences and this can produce serious social dislocation. These are themes that were picked up by former B.C. Supreme Court Justice, Thomas Berger (1977), in his classic report on the Mackenzie Valley pipeline. The message was elegant, yet simple. In essence it boils down to the proposition that megaproject staples development is not sustainable and should be avoided as a linchpin in future northern economic planning (Rees 1978).

Yukoners seem to be galvanizing around this simple message today. Many of them believe that the whims of world markets should no longer dictate the strength and resilience of their socio-economic fabric. New attitudes are developing and, arguably, these new attitudes support the desirability of a sustainable economy in the territory. In theory such an economy will be more diverse — a mixture of primary material extraction, cultural industries, manufacturing and service provision rather than one based on megaprojects or dominant single industries such as mining.

These new attitudes were reflected in the recent territorial election in Yukon, which put a minority New Democratic Party government in place. The NDP campaigned on a platform that they would promote more sustainable development if they were elected and their continued legitimacy rests on their capacity to implement this platform through initiatives such as import substitution. However, as argued below, implementation could prove difficult for numerous reasons.

Among the most significant of these reasons is the fact that the concept of sustainable development and the policies which support it are difficult to define and sound like political rhetoric (McRobert 1986). In addition, it is far from clear what sectors of the economy can be stimulated to achieve sustainable development.

Hypotheses

If one studies economic history in any detail, particularly the major transitions between hunter-gatherer, early agricultural, and various industrial configurations, one finds that economic growth is not a purely economic phenomenon (Braudel 1977). It is the result of a combination of factors including demography, culture, availability of capital, technology, geography, and politics to name only a few. Two of the key actors that must be taken into account are attitudes and values because they shape individual behavior patterns and, in turn, constrain the efforts of planners to devise solutions to certain perceived social or environmental problems (Cone and Hayes 1984). Since individual attitudes about economic development in Yukon seemed to be a "wild card" in the current government initiatives, we set out to study them with this multi-disciplinary perspective at the forefront of investigation.

Our general hypothesis was that Yukoners would probably indicate support for certain "motherhood" policy initiatives such as import substitution. However, we also suspected that the "nuts and bolts" of implementation would pose problems and flare ideological differences. For example, we felt that the importance of certain philosophical elements in the frontier psyche (for example, the free market) would make it difficult to identify a consensus on how to promote self-sufficiency in the territory. In addition to these general hypotheses, there were numerous others, discussed more fully in the Results section.

Method

In order to do our study in a short period of time, we decided to concentrate on the attitudes and perceptions of a fairly small sample of Yukon residents. Those interviewed ranged from government officials in the YTG who had been involved with formulation of the *Yukon 2000* document to local entrepreneurs who had attended the Faro conference in June.

In the end, our sample included the views of 30 individuals, who lived mainly in the Whitehorse area. It was assumed that problems posed by using this small sample would be offset by relatively detailed interviews of "stakeholders" and the fact that most of the people we interviewed held special positions as opinion-formers and policy-makers in the territory. According to certain theorists, research carried out in this way can reveal interesting and relevant exploratory information (Morley 1983; Trist 1976).

Two students (Chris Smit and the author) did the interview work. Interviews generally lasted between an hour and two hours, depending on time constraints. Some of the respondents who were unable to meet with us were provided with questionnaires and responded with short written answers.

The questionnaire itself was divided into five main sections. The first and second sections dealt with perceptions about population futures in Yukon and knowledge of previous studies on economic development. In order to obtain some kind of comparative and reliable basis for assessment of the various attitudes on population growth, five different scenarios were plotted on a graph. These scenarios included high, medium, low, no, and negative growth forecasts for Yukon over the next twenty years. Respondents were asked to identify: (1) which one they believed would be desirable and (2) which one they felt to be likely.

No other similar data were collected; in the balance of the questionnaire we asked respondents open-ended or multiple-choice type questions. The third section focussed on attitudes about the prospect for a sustainable economy in Yukon. The last two sections examined northern provincehood and aboriginal self-government respectively. In addition, some basic personal information was collected.

Results

In presentation of the results, the data derived in the third section of the questionnaire (on Sustainable Development) are concentrated on, as indicated above. However, a few relevant highlights from other parts of the study will put the comments on sustainable development in context.

Perceptions about population growth and economic development

Of the five scenarios plotted on rates of population growth to 2025, the majority of respondents felt the low growth scenario was both desirable and likely. The most frequently mentioned reason why low growth was desirable is that Yukoners could retain greater control over development. Similarly, low growth was felt to be likely because of constraints on economic growth due to weak metal markets and limited opportunities in other sectors.

Since the *Yukon 2000* discussion paper attempts to address the problems related to the transient nature of the white population, we thought it would be relevant to enquire as to attitudes towards this issue. Some of the consequences of the constant turnover, particularly among young people and recent immigrants who are attracted to the north by high wages, include loss of political and social integrity in the communities and higher costs for constant retraining. Those people we spoke to suggested that they did not perceive the constant turnover in population to be a significant problem now. This perception may reflect the fact that the break point between those who stay and those who leave Yukon, which was determined to be 4 years by Duerden (1983) using data collected in the 1970s, has now increased to about six years (YTG 1985a).

Another issue which was examined is decentralization. As most people who have visited Yukon realize quickly, the vast majority of residents live in the major centres — Whitehorse, Dawson, Watson Lake and Faro. Collectively, these cities contain about 85% of the population in the Territory (Duerden 1981).

The question that arises from this population distribution is whether it might be appropriate for government to encourage decentralization of certain services. To the extent that sustainable development should be based on local resources, we felt this was a relevant matter to pursue. Consequently we asked respondents their views on decentralization and

government plans to relocate certain offices to more remote locations. Generally most people agreed that Yukon's population is too centralized but they did not perceive centralism as a problem. Moreover, even if they did acknowledge centralization as a problem, respondents doubted that anything could be done about it. It should be kept in mind that our sample was primarily made up of Whitehorse residents and it is likely we would have obtained different results if we had interviewed Yukoners in Watson Lake and Dawson who would benefit from decentralization.

We also asked respondents about their perceptions on sectoral growth in the next decade. Of the options that we listed, tourism proved most popular by a wide margin. However, many respondents also identified increased wilderness activity, the outfitting industry, land claims and energy development as potential sources of future economic growth. The results for each of these sectors has a bearing on this analysis and should be briefly reviewed here.

We had anticipated that many people would have a healthy degree of skepticism about the future of mining in the territory given recent history and other factors such as Third World competition (Fischer 1986). Instead we found that most respondents believe mining has a good future in Yukon. However, these people also acknowledged that world markets were the important unknown variable in their forecasts. Moreover, their optimism probably reflects the recent reopening of Faro (see Lourie 1986) and contradicts other trends in mineral recycling and conservation identified and described by futurists such as Naisbitt (1984).

Since the 1982 slump in mining, tourism has been touted as one of the largest potential sources of economic growth in Yukon's future. Currently tourism continues to play an important role but our study suggests the "bloom is coming off the rose." Most people endorsed the notion that tourism could provide economic growth but about half a dozen suggested there was a need to recognize some kind of ceiling to growth in the industry, otherwise the quality of life for Yukoners could be adversely affected.

Some of these respondents also acknowledged that this ceiling might have been reached already and it would be necessary to take a new approach to this industry in the future. This conclusion is also supported by recent experience in the industry. In 1985, close to 450,000 people visited Yukon and these visitors spent approximately $87 million (YTG 1986b: 14). However, many of these visitors now merely stop briefly in Whitehorse on their way to Alaska. Ironically, road improvements in the territory have served to facilitate more rapid passage through Yukon communities. Visitors who previously spent a day or a couple of days in Whitehorse now spend hours, snacking at MacDonald's rather than taking a room and a more substantial meal. Thus, the key issue in terms of a sustainable perspective is not how to attract more visitors but how to attract visitors to stay in communities like Whitehorse and Dawson for a longer period.

In terms of most of the theoretical objectives for a sustainable economy, it would be difficult to imagine sectors that are more ecologically-appropriate than those relying on wildlife. Whether the activities are traditional or based on the sports hunting and fishing industry, they should be considered as the foundation of a more sustainable economy in the north (Dacks 1981; Dickinson and Herman 1979).

Regarding the first sector, it is undeniable that wildlife harvesting continues to inject many hundreds of thousands of dollars into the Yukon economy. Duerden (1986) has recently completed research on the Teslin community which shows substantial reliance on traditional foods. However, there are also signs of a decline because skills are not being passed on between generations. Similarly, fur trapping continues to contribute to the Yukon economy even though the anti-trapping movement has cast an ominous shadow over the future of this industry. Respondents generally reflected these perceptions in their opinions on the economic importance and viability of traditional activities in the next decade.

Respondents were much more optimistic about the potential for growth in the established outfitting industry and the opportunity to link traditional native land skills to other wilderness activities such as whitewater rafting. The outfitting industry is a multi-million dollar enterprise (see Oshtashek 1982) and has been for many years. The past decade has also seen expansion of interest in wilderness activities in Yukon. Some respondents believe both these industries will continue to expand in the future. However, it is unclear whether expansion will pose land use conflicts and if it does, how these can be satisfactorily resolved (Jull 1986).

Another perception of certain respondents was that the settlement of the Yukon Indian land claim would bring a boom to the territory of considerable magnitude. While no respondents felt that it would match that experienced in Alaska in the early 1970s when the settlement was concluded there (Berger 1986; Thomas 1986), many did think that numerous businesses would prosper. However, it also should be noted that an equal number of respondents doubted that much land claims cash would be available and that what would be invested locally could have much of a socio-economic impact.

The potential for forestry in Yukon is restricted by the amount of suitable area available for harvesting and rates of forest growth. While the Liard Valley has provided a basis for a limited industy in the past, most lumber in the territory is imported (DPA Group Inc. 1986). In fact, only 3 per cent of the estimated amount available for cutting on a sustainable basis is now harvested. Despite this, few respondents identified this sector as an important contributor to economic growth in the future.

One resource which was mentioned frequently as an untapped source of future energy for Yukon was hydroelectric power. At present approximately 250,000 MWH are generated each year. It has been estimated that up to 13.5 million MW of hydro power are available in Yukon, primarily on the Yukon River. However it is unlikely that most of this capacity will be tapped because large scale damming would require flooding river valleys. Nevertheless, numerous respondents suggested that the potential for micro-hydro was considerable and some noted that a recent report by Boreal Engineering Services (1985) has confirmed this fact.

Other potential sources of economic growth in the territory that were listed in our questionnaire included government, commercial harvesting of fish and wildlife and small businesses. Of these, government was indicated by a handful of people as a potential source of growth. Moreover, small business was supported by many respondents, a reflection

of the current conventional wisdom about the importance of small business in economic growth. However, respondents were not optimistic about the prospects for water or electricity exports and did not feel that commercial harvesting of wildlife and fish was going to become an engine of economic growth in the next decade.

TABLE 1
Types of Responses to Question
"What do you understand by Sustainability?"
(Numbers of Respondents in brackets)

Greater Self-Reliance/Use of Local Labour and Goods	(10)
Renewable-Resource Oriented Production	(5)
Insulation from Boom/Bust Cycle	(7)
Small Scale Production	(2)
Other	(3)
Does Not Know/No Response	(3)

Prospects for sustainable development

As a point of departure in analyzing attitudes about sustainable development, we felt it was necessary to find out how respondents defined sustainability.

The results of our attempt to have respondents define sustainability reflect many of the ideas about self-sufficiency that were described above, as Table 1 shows. What is surprising however, was the fact many respondents had no idea what sustainable development is. Some people see sustainable development as renewable-resource based production while others perceive it as insulation from the boom and bust cycle. Presumably this latter characterization would qualify expansion of government services as a basis for a more sustainable economy, an approach which would seem to defy the spirit of Schumacher's thesis in *Small is Beautiful*.

We also inquired as to the respondent's perceptions of the extent of public support for self-sufficient development in Yukon. Not surprisingly, the majority of respondents felt the public did support the policy. However, some resistance was also pointed out. Six respondents were not sure whether the public supports the move towards self-sufficiency and the majority of respondents expressed doubt as to whether the public understands the policy.

The most visible policy initiative of the YTG with respect to sustainable development is import substitution. This initiative has special appeal to northerners because of the high cost of transporting goods to markets and the massive leakages of capital that take place as a result of this phenomenon (Huskey 1984).

To see whether or not support for import substitution existed, we asked respondents whether they supported the principle. Apart from two individuals, every respondent gave the policy their vote of approval.

We also asked about the problems perceived with the policy initiative. The barriers to import substitution that our respondents identified are summarized in Table 2. Most frequently identified barriers included: (1) higher prices and (2) lower quality of goods and services. However, some respondents felt that these barriers could be overcome if the YTG undertakes careful planning and identifies which sectors should be stressed in plans for import substitution. This planning process has already begun. Last year a Calgary-based consulting firm was hired to prepare a preliminary study. Their report was released this past summer and it suggested that import substitution is feasible in numerous sectors (DPA Group Inc. 1986). The report was most enthusiastic about the potential for cottage industries and renewable resource development in the energy, forestry and agriculture sectors.

TABLE 2
Types of Barriers to Import Substitution
Identified by Respondents
(Number of Respondents in brackets)

Higher Prices	(16)
Lower Quality of Goods and Services	(4)
Land Use Conflicts	(3)
Cost to Government	(2)
Insufficient Population Base	(3)
Distance to Export Markets	
Free Enterprise Ideology	

A more difficult issue is the extent to which government intervention should disrupt the market. Arising from Table 2 are results which support the hypothesis that many people fear import substitution will disrupt free market processes by making goods more expensive and reducing their quality. Given the ideological adherence to freedom in the marketplace evidenced in Yukon historically, implementation of the policy will no doubt prove contentious.

We also asked respondents what they thought about the steps taken by the YTG to date. More than one third of the respondents felt no meaningful steps had been taken by July 1986. Eight people felt that the steps that had been taken were positive, while nine people either did not know or refused to respond. Finally, a handful of people said that the actual steps taken to date had had a negative impact on public perceptions.

In the view of many people who support import substitution, the sector most likely to provide a basis for sustainable development in Yukon is agriculture. In fact, one of the greatest ironies for many Yukoners is that farming was a far more important part of the territory's economy eighty years ago than it is today (MacKinnon 1982). Respondents felt that interest in local farming has declined because of high costs, low profits, poor soil quality, climatic restrictions and improved transportation networks (Agriculture Canada 1984; DPA Group Inc. 1984).

Of those people we interviewed, over eighty percent of respondents felt agriculture should be promoted. Dissenting voices argued that agriculture could displace wildlife and that anything more than "hobby-farming" should not be supported.

Conclusion

To conclude, it must be stressed that the results reported here are only preliminary. Nevertheless, this study suggests that Yukoners want greater control over their economy. Moreover, they generally view the recent efforts of the YTG in the areas of import substitution and renewable resource management favourably. However, there is no consensus on

how to encourage greater self-sufficiency in Yukon or what sectors should lead the movement towards sustainability.

Future interpretation of the data will no doubt reveal interesting implications for policy forthcoming from the study. However, the present results show that the YTG has much more work to do in both disseminating information and clarifying the costs and benefits of the policy initiatives they are undertaking. Otherwise it is possible that the initiatives will be perceived as merely rhetorical devices to gain votes and lacking in substance. Nevertheless, I commend the YTG for undertaking *Yukon 2000* and look forward to future results of this and other related initiatives.

Acknowledgments

The author gratefully acknowledges the technical support of Mr. Tony Hodge, Department of Economic Development: Mines and Small Business, Yukon Territorial Government in helping him to carry out this study.

References

Agriculture Canada. 1984. Yukon Agriculture 1984: State of the Industry. Agriculture Development Services Report No. 2. Whitehorse.

Berger, T.R. 1977. Northern Frontier, Northern Homeland: The Report of the Mackenzie Valley Pipeline Inquiry, Vol. 1. Ottawa: Department of Supply and Services.

_____ 1986. Village Journey: The Report of the Alaska Native Review Commission. New York: Hill and Wang.

Boreal Engineering Services Ltd. 1985. Micro Hydro in Yukon, Volume 1. Report prepared for the Energy and Mines Branch, Department of Economic Development, Mines and Small Business, Government of Yukon under the Canada/Yukon Conservation and Renewable Energy Demonstration Agreement.

Braudel, F. 1977. Afterthoughts on Material Civilization and Capitalism. Trans. P. Ranum. Baltimore: John Hopkins University Press.

Cone, J.D. and Hayes, S.C. 1984. Environmental Problems/Behavioral Solutions. New York: Cambridge University Press.

Dacks, G. 1981. A Choice of Futures: Politics in the Canadian North. Agincourt, Ont: Methuen Publications.

Daly, H. 1980. An introduction to the steady-state economy. In: H. Daly (Ed.) Economics, Ecology and Ethics: Essays Towards a Steady-State Economy. San Francisco: W.H. Freeman Co.

Dickinson, D.M. and Herman, T.B. 1979. Management of Some Terrestrial Mammals in the Northwest Territories for Sustained Yields. Yellowknife: Science Advisory Board, Government of the Northwest Territories.

The DPA Group Inc. 1986. Assessment of Import Substitution Opportunities: Canada/Yukon Economic Development Agreement. Prepared for: Economic Policy, Planning and Research Department of Economic Development, Mines and Small Business, Yukon Territorial Government.

_____ 1984. The Feasibility of A Yukon Dairy Farm and Processing Plant, Phase I Report. Prepared for D. Bodry and Partners.

Duerden, F. 1981. The Development and Structure of the Settlement System in the Yukon. Whitehorse: Yukon Territorial Government.

_____ 1983. Migration patterns and Yukon settlements, 1968–1978. Musk-Ox, 32, pp. 10–21.

_____ 1986. Teslin: The Indian Village and Community Economy — An Appraisal. Prepared for the Teslin Indian Band, January 1986.

Fischer, M. 1986. Faro mine brings hope to Yukoners. The Globe and Mail, Sept. 1, 1986, p. B5.

Fuller, S. and McTiernan, T. 1987. Old Crow and the Northern Yukon: Achieving sustainable renewable resource utilization. Alternatives, 14(3):18–25.

Hamelin, L.-E. 1979. Canadian Nordicity: It's Your North, Too. Trans. W. Barr. Montreal: Harvest House.

Huskey, L. 1984. Import Substitution in Frontier Regions. Paper presented to Western Regional Science Conference, Monterey California, February 1984.

Innis, H.A. 1930. The Canadian North. University of Toronto Monthly, Vol. 30 (January), pp. 163–65.

_____ 1956. The Fur Trade in Canada. Toronto: University of Toronto (1st. Ed., 1930).

International Union for the Conservation of Nature and Natural Resources (IUCN). 1980. The World Conservation Strategy. Zurich: IUCN.

Jull, P. 1986. Politics, Development and Conservation in the International North. Ottawa: Canadian Arctic Resources Committee.

Lourie, B. 1986. Northern Resource Decision-making: A Case-Study of the Faro Mine. Paper presented to National Student Conference on Northern Studies, Ottawa, Ont., November 18 and 19, 1986 (Paper in this volume).

Lysyk, K.M., Bohmer, E. and Phelps, W. 1977. The Alaska Highway Pipeline Inquiry. Ottawa: Ministry of Supply and Services.

MacKinnon, C.S. 1982. The rise and decline of agriculture in the Mackenzie District and the Yukon. Musk-Ox, 32.

McCandless, R. 1985. Yukon's Wildlife: A Social History. Edmonton: University of Alberta Press.

McRobert, D. 1986. Canada and the World Conservation Strategy. Probe Post, 9(1), pp. 39–33.

_____ 1984. The Consequences of Balanced Development in Northern Canada: The Ecological Implications of an Exotic Ideology. Unpublished Major Paper for Master of Environmental Studies degree, Faculty of Environmental Studies, York University, Downsview, Ontario. 494 pp.

Morley, D. 1983. Applied geography as action research: The St. Lucia Energy Futures Project. Geographical Research Forum, No. 6, September 1983.

Naisbitt, J. 1984. Megatrends: Ten New Directions Transforming Our Lives. New York: Warner Books.

Ostashek, J. 1982. Value of Northern wildlife: Outfitting industry. In: Transactions of the Forty-Sixth Federal-Provincial Conference. Ottawa: Canadian Wildlife Service, Environment Canada.

Page, R. 1986. Northern Development: The Canadian Dilemma. Toronto: McClelland and Stewart.

Rea, K.J. 1968. The Political Economy of the Canadian North. Toronto: University of Toronto Press.

Rees, W. 1978. Development and planning north of 60 degrees: Past and future. In: R.F. Keith and J. Wright (eds.) Northern Transitions: Proceedings of the Second National Workshop On People, Resources and the Environment North of 60. Ottawa: Canadian Arctic Resources Committee.

Robinson, M. and Ghostkeeper, E. 1986. Native and Local Economics: A Consideration of Economic Evolution and the Next Economy. Unpublished M.S., 29 pp. (On file with author).

Schrecker, T. 1983. The Conserver Society Revisited. A discussion paper prepared for the Science Council of Canada. Ottawa: Ministry of Supply and Services.

Schumacher, E.F. 1973. Small is Beautiful: Economics as if People Mattered. New York: Abacus.

Task Force on Northern Conservation. 1984. Report of the Task Force on Northern Conservation. Ottawa: Department of Indian Affairs and Northern Development.

Theberge, J. Nelson, J.G. and Fenge, T. 1980. Environmentally Significant Areas of the Yukon Territory. Ottawa: Canadian Arctic Resources Committee.

Thomas, M.E. 1986. The Alaska Native Claims Settlement Act: conflict and controversy. Polar Record, 23(142), pp. 27–36.

Trist, E. 1976. Action research and adaptive planning. In: A.W. Clark (Ed.), Experimenting with Organizational Life. London: Plenum.

Usher, P. 1981. Staple production and ideology in Northern Canada. In: W. Melody *et al.* (eds.) Culture, Communication and Dependency. Norwood, New Jersey: Ablax Publishing.

Valaskakis, K., Sindell, P., Smith, J.G., and Fitzpatrick-Martin, I. 1979. The Conserver Society: A Workable Alternative for the Future. New York: Colophon Book.

Watkins, M. 1977. From underdevelopment to development. In: M. Watkins (Ed.) Dene Nation: The Colony Within. Toronto: University of Toronto; pp. 84–102.

Yukon Territorial Government. 1985a. Population Estimates of Yukon, June 1, 1985. Whitehorse: Bureau of Statistics, Executive Council Office.

_____ 1985b. The Future of the Yukon's Renewable Resources: A Discussion Paper. Whitehorse: Dept. of Renewable Resources.

_____ 1986a. Yukon 2000: Building The Future. A public discussion paper on the Yukon development strategy. Whitehorse: Executive Council Office.

_____ 1986b. Yukon Economic Outlook, 1985–87. Whitehorse: Policy Planning and Research Branch, Department of Economic Development: Mines and Small Business.

Zaslow, M. 1971. The Opening of the Canadian North, 1870–1914. Toronto: McClelland and Stewart.

FOLKLORIC EXCHANGE BETWEEN LABRADORIANS AND NEWFOUNDLAND FISHING FAMILIES "ON THE LABRADOR"

Clara J. Murphy

Department of Folklore, Memorial University of Newfoundland, St. John's, Newfoundland A1C 5S7

Level: Master's

Abstract

This paper examines the genres of folkloric exchange and transmission between two populations of participants, Newfoundlanders and Labradorians, in the summer Labrador coastal fishery. Analyses of personal experience narratives and songs reveal the culturally symbiotic relations between Newfoundlanders and Labradorians. For the past 160 years, Newfoundlanders have had control of premises "on the Labrador" formerly belonging to firms from England, Jersey and Quebec. The Newfoundland fishermen fished either as stationers (land-based family units) or as floaters (schooner crews with one or two female cooks and salters). Their advent brought Labradorians in contact with a supply of potential spouses as well as a supply of potential employers and/or employees. The annual seasonal migration gave rise to many occasions for exchange of folklore and folklife between Labradorians and Newfoundlanders. These occasions included "harbour days", lulls in economic activity due to weather; Sundays, when no work was carried out due to religion; and the "waiting for the boat" period at the end of the season. During these periods, visiting of other family groups was the main vehicle for this cultural exchange. The folklore exchanged was then carried home to the winter communities in Newfoundland and Labrador.

Data for this study was collected during fieldtrips on the Labrador in 1984 and 1986. Archival materials from the Labrador cultural-historical archive of *Them Days* and the Memorial University of Newfoundland Folklore and Language Archive were also consulted.

Key words: Labrador coast, Newfoundland fishing families, Labradorians, cultural symbiotic relations.

Résumé

L'étude décrit les genres d'échanges folkloriques et leur diffusion entre deux populations de participants, Terre-neuviens et Labradoriens, dans les zones de pêche estivale du littoral du Labrador. L'analyse des chansons et des récits d'expériences personnelles met en évidence les relations symbiotiques entre Terre-neuviens et Labradoriens sur le plan culturel. Au cours des 160 dernières années, ce sont les Terre-neuviens qui ont possédé les installations du littoral labradorien appartenant précédemment à des entreprises d'Angleterre, de Jersey et du Québec. Les pêcheurs terre-neuviens étaient, soit des sédentaires (groupe familial basé à terre), soit des non-sédentaires (équipage comprenant une où deux cuisinières ou saleuses). Leur venue mit les Labradoriens en contact avec des conjoints éventuels, et aussi avec une réserve de personnel ou d'employeurs. La migration saisonnière offre de nombreuses possibilités d'échanges folkloriques entre Labradoriens et Terre-neuviens: séjours au port, période d'inactivité économique due au temps, dimanches chômés pour raisons religieuses, et attente pour le bateau en fin de saison. Au cours de ces périodes, ce sont les visites dans d'autres familles qui constituent le principal véhicule d'échange culturel. Les activités folkloriques sont ensuite introduites à la maison du lieu de résidence hivernale, à Terre-neuve ou au Labrador.

L'auteure a recueilli les données de cette étude en 1984 et 1986, au cours de travaux au Labrador. Elle a également consulté les archives culturelles et historiques du Labrador de *Them Days* et celles, linguistiques et folkloriques, de l'Université Mémorial de Terre-neuve.

Mots-clés: Littoral du Labrador, familles de pêcheurs terre-neuviens, Labradoriens, relations culturelles symbiotiques, genres de folklore, échanges, diffusion.

Introduction

For at least two centuries many Newfoundland fishermen have spent summers fishing in Labrador. Schooners go north, often as families, sometimes as agnatic or community based crews, and there the two populations — Newfoundlanders and Labradorians — mix. Although the two populations have many similarities, they also have many differences. Over the years there has been much cultural exchange between them, particularly in the form of folklore and folklife. It is with the forms and contexts of this folkloric exchange that this paper is concerned.

Folkloric exchange between Labradorians and Newfoundland fishing families takes place in social and occupational contexts. Items of folklore are passed from one group to another through observation and participation. Most of the exchange is done verbally through conversation, story telling and singing. In 1984 my following of the sea route taken by my ancestors from Conception Bay, Newfoundland to Cutthroat, Labrador, presented yet another occasion for the exchange of narratives, songs, and music which had been heard by generations of Newfoundlanders before me. The typical Labradorian reaction to my being a Newfoundlander was the lighting up of eyes followed by something like: "My grandmother comes from Conception Bay" or "My, how we loved to see the Newfoundlanders coming". I met many Labradorians who traced their ancestry to Newfoundland fishing families.

While returning from Nain to Goose Bay, I was invited to make a stopover in Rigolet to spend three days at a summer fishing station at Ticklorak Point (population: two families — four adults and four children). George, the head of one household, was the grandson of a man from White Bay, Newfoundland, who had married four times on the Labrador, once to a Newfoundlander. George's maternal great grandfather had been an Englishman and his maternal grandfather had been a cabin boy from Wales who deserted ship on the Labrador at the age of fourteen. George himself had no children but had adopted a relative as his son. This

son, the head of the only other household at Ticklorak Point, had married a Newfoundland widow with three children who had come to Labrador to teach. While living and fishing with them, I was able to hear and record stories and songs of the old days. In May of 1986 I returned to Labrador to visit the families in their winter community, Rigolet, to learn more about life past and present, especially attitudes towards Newfoundlanders. On this occasion I also interviewed other members of that community. I found the structure of George's family to be typical of the structure of many Labradorian families. Please note that Labradorian, as used in the paper, is anyone of either Inuit, Innu or European descent.

One Labradorian said Newfoundlanders always called Labrador their second home. Schooners would come from Newfoundland to the Labrador community where she spent her summers. Although the crews were male, nearly every schooner had a female cook aboard. During the short, but busy fishing season little socializing took place for as Druscilia said:

> They wouldn't have much time to visit except Sunday. Some would be too tired to come ashore (even on Sunday). But they used to have good fun then [especially] when they'd be there after the fishing be over. They'd have the traps ashore in the evening after supper. They had to play cards and sing songs until three-four o'clock in the morning to go back.
>
> (Murphy 49, MUNFLA 86-013/C8625.)

Druscilia went on to say that sometimes she and her friends would go aboard the schooners to visit the girls to have a cup of tea and a chat. She and other informants reminisced about the good music and songs that the Newfoundlanders always brought with them. Newfoundland informants praised the Labradorians for their singing and playing abilities.

Songs

In the fall Labradorians moved inland to live on their trapping grounds in little communities of one or two families. It was the custom to gather in one place, usually the Hudson's Bay Company post, for Christmas. This gathering became the occasion for feasting, dancing, and the singing of songs. A Labradorian now living in Goose Bay, spoke in great detail about songs she and other members of her family had composed. At age fifteen, she composed a song about her sisters and their boyfriends in Newfoundland. The song, what folklorists call a moniker song, was thirty-two verses long and included everyone at the gathering in addition to the Newfoundland crowd.

> I'd compose [songs] around Christmas and forget them unless somebody wrote them down. I think that one about Cupids was copied and was in Cupids. That's where I did pick up a lot of the verses I had forgotten because they had taken it back there and kept it alive for awhile.
>
> (Murphy 53, MUNFLA 86-013/C8629)

Clarice went on to say the younger people mentioned in the song had kept on singing the song because it was about them. She reiterated that songs were composed for special occasions, sung and then forgotten unless someone wrote them down. To her, a song was "really a record of the things we were doing." While hers were always romantic songs about boys and girls teasing each other, her brother and other fishermen composed songs about fishing or about working at the nearby whaling factory. One song composed by her brother (another moniker song) listed all the bankers (vessels that fished the Bank fishery) and their skippers and recorded the visit of bankers as an occasion for having a dance. Moniker songs serve an oral historical purpose besides their synchronic function of honouring local people — it is often by means of such songs that local history is retained.

Songs were also used as a vehicle for maintaining acceptable behaviour. When one Newfoundland merchant outfitted Labradorians that another Newfoundland merchant had refused, the event was duly noted in a song which George remembered and sang for me.

Narratives: shared foodways

Newfoundland stories record the Labrador people awaiting their arrival in the spring, coming out to the schooner or steamer to meet them and carry them to their houses. Friendships developed based on shared respect for fishing ability, and on common interests in singing, dancing, yarning, and in cruising (visiting). In 1894, Lydia Campbell, the daughter of an English man and an Inuit woman wrote:

> It was and is a Labrador custom to give anyone, dark or white, something to eat while they were at our house and bedding so the Indians was always kind to us.

This custom is still carried on by Labrador and Newfoundland fishermen today. The story is told of a Newfoundland floater crew in the early 1900s cooking a meal of seal meat given to them by a Labradorian. Another Labradorian who happened along at meal time was given some seal. After chewing on it awhile he asked if the seal had been taken that morning. When asked why, his reply was "It's still warm." Evidently, he did not have a tradition of cooking seal meat. Although Newfoundlanders and Labradorians enjoyed and shared the same food it was not always prepared in the same way.

Labradorians might have come to enjoy Newfoundland food out of pure necessity as the following story will illustrate. This incident took place in 1904 when the schooner the *Winnie F. Tuck* met with a storm and went to a Labrador cove to make some repairs.

> Two families of natives about fourteen or fifteen of them were there. It was like we were sent in there to save people. We saw something crawling down to the beach. We sent a boat ashore and found the two families starving. They lived on ducks' eggs and gull eggs and mussels for two months. We had six fishing crews aboard about five people on a crew including girls and their families. Each family had their own summer grub aboard. They all chipped together to give the natives some. We were there about five or six hours and then left.
>
> (MUNFLA, 75-257, pp. 9-10)

> Labradorians were by no means always on the receiving end of the relationship with Newfoundlanders. The Inuit contributions of the manufacture of sealskin boots, travel by dog sled and techniques of seal hunting are probably better known by Newfoundlanders than the Innu contributions of snowshoes, canoes and intimate knowledge of the habits of caribou. Newfoundlanders, like the Inuit, were coastal people and their winter trade was lumbering, coasting, and sealing rather than hunting and trapping. Labradorians often greeted Newfoundlanders with a gift of seal or birds and sent them home with sealskin boots, grasswork, and good advice. They also provided them with much needed services. Reverend Waghorne wrote that Newfoundlanders depended upon Labradorians as well as the travelling doctors and their fellow Newfoundlanders for medical assistance.

Folk medicine: the Sandwich Bay Nurse

This is a story told by Margaret Davis of her grandmother, the Sandwich Bay Nurse.

> Years ago hundreds of schooners would come from Newfoundland. One particular summer one of the fishermen got a badly infected hand. They heard about Grandmother Sheppard, of course, so he was brought to her. She operated on him. She made a cotton bag, sort of like a mitt, and told my mother to go and get several maggots to put in it. She put the bag with the maggots in it on his hand and left it on overnight. Next morning the hand was cleaned right out. In the meantime, Grandmother had steeped out some ground juniper bark and prepared a salve out of the pulpy part of the juniper. She mixed a bit of cod oil into her juniper salve. Next morning she bathed the hand in steeped juniper, applied some of her salve and dressed it. It wasn't long before the fisherman could go back to his schooner.
>
> (Margaret Davis, *Them Days*, 2:4 (1978) p. 44)

Material culture: skin boots for boats

This story told by Alder Ford of Makkovik demonstrates the Newfoundlanders' appreciation for Labradorian sealskin boots. In talking about the price of boots, Mr. Ford said:

> The most ones that'd buy boots was the Newfoundland fishermen in the summers. They'd have boats that they'd exchange for skin boots, they'd rather have skin boots than money. If you wanted a boat you'd give so many pairs of skin boots. I remember my uncle gave forty pairs of boots for a motor boat with no engine in her.
>
> (Alder Ford, *Them Days*, 4:2 (1978), p. 9)

Many Labradorians lived in close contact with Newfoundlanders. George, my friend from Rigolet, told me that the Labradorians often used fishermen's huts for "warm ups" when travelling in the winter time. If any food was taken, a pelt was left in return. His father enjoyed going where the Newfoundland fishermen were for economical as well as social reasons. This is a story told to him by his father.

Narrative: George's story; exchange of methodology

> [He] used to fish out of their traps too sometimes, he told me. Get out early in the morning, you know. He'd jig his boat load, punt load of fish out of one of the Newfoundland traps and get ashore again before the boats would come. Went out early one morning. Heard the boat coming. Started to pull out his jigger and got his jigger hooked in the bottom of the trap. He cut his line but the jigger was still in the bottom of the trap. He went to one side then. You could fish anywhere so long as you didn't fish out of the trap. And when they got the jigger, the motor boat, they run over to him and they said: "We found your jigger. I guess this (is) yours. It wasn't here yesterday in the bottom of our trap." The old man told him "yes". The Newfoundlander said, "You're not careful! You didn't jig out of as many traps as I jigged out of". He said, "You put your net out next time. Sound the water. See how much, how deep the water is in the bottom of the trap". "Then," he said, "take the net off," he said, "and let the jigger go about so far from the bottom of the trap and load her down . . . Newfoundlanders often gave the Labrador people [advice] tell them, they'd be jigging see, tell them "come up alongside boys and fill up your boat".
>
> (Murphy 7, MUNFLA 86-013/C8675)

The giving away of fish that could not be quickly processed was a common custom among fishermen. In this story George's father not only gets away with stealing fish but he is also taught the proper technique to steal successfully from the traps.

The Newfoundlanders were not always so helpful. George tells this story from his grandfather's time about a schooner anchored in Black Island Tickle. The crew, followed later by the Captain, left the schooner in the morning and rowed away to the trap.

Narrative: Arthur defies the law to save his sons from wrongful accusations

> So the crew came back before the skipper did and they found the cook lashed to the mast. They asked her what happened and she said there was a Labrador man came down through the tickle and came aboard. I don't know what he done with her but he lashed her to the mast he said. They used to have Justices of the Peace then who could have court but it was the magistrate they got for this case. Indian Harbour, which is about forty miles from this place, well that was where they were going to hold court to about this girl that was lashed. They went around to all the places. They picked up all the men, the magistrate did, and they came to Rocky Cove and there was quite a long bar there. They landed on the bar and was walking in. My grandfather, Arther, went to the woodpile and got a stock and met them and drove them back. Wouldn't let them take any of his sons. So that's alright. They went again and everyone that was around fishing they lined them all up. They told the girl to pick out the

> one that lashed her. And there was one man there he could hardly get out a word for stuttering and I don't think he was too bright by what I heard, you know. He was one of those I don't know what you'd call it. He used to stutter a lot. And she pointed to him. This man "That's the man there if he's on earth." Now this old man, he was quite an elderly man from what I hear, he took crying. He said "No miss. Miss, I never seen the sky over you before." He tried to say something else but before he got it out the magistrate made him shut up. That was enough. They took him out anyway. Took him out to St. John's. He was gone to St. John's. But in the end she confessed the skipper did it himself after the crew left.
>
> (Murphy 45, MUNFLA 86-013/C8621)

George went on to say that the Labrador man never brought any charges against the girl and never received any compensation for lost worktime. George had a few of these negative stories about Newfoundlanders and the Newfoundland government in his repertoire but mostly he and the other Labradorians stressed the positive side, the caring and sharing.

The sharing was not only of physical resources. It could and did extend to the psychic. George narrated a story his father had told him about seeing a phantom schooner one Sunday evening that no one else had seen.

Precognitive warning

> So anyway he was sat down in the window the next Sunday evening and he seen the same schooner coming through the Tickle. He went out to Uncle Albert and told him there's the schooner now I seen last Sunday coming through the Tickle. The schooner came in and anchored. The skipper and two or three more of them came ashore. And my father said to them: "Did you pass through the Ice Tickles here last Sunday?" The skipper said "No, I never came through here. I came on up now." My father told him "I saw your schooner come through here last Sunday evening handy about the same time." "Well," he said, "I dare say you did." The night before I left home, my mother saw me stood up to her bedside with my oilclothes on. "So for that reason that you saw me come through last Sunday and my mother saw me I was intending to go home straight, I'm going to turn to shore. I'm not going to leave and when I gets home, if I lives to get home, you'll hear from me." So anyway, that Fall on the last boat come down my father had a barrel of clothes. He had a letter from the man saying that his schooner sprung a leak and he lost everything he had. But there wasn't any lives lost. So the Newfoundland skipper thanked him and said that between him, my father, and his mother that was what saved his life and his crew. Now that's the story my father was telling me you know. It was a warning I suppose eh, you know.
>
> (Murphy 7, MUNFLA 86-013/C8675)

Thus it was that a Newfoundland fisherman heeding the precognitive warnings of his mother and the Labrador man exercised caution and made the trip safely home.

Conclusion

Some summers were good. Some summers were bad. Through the stories from both sides of the water runs the constant theme of how enjoyable it was to be on the Labrador. On Sundays and harbour days, and in the Fall the Newfoundlanders and Labradorians had house dances. Researcher Kleivan writes:

> We do have evidence that the missions blamed both the earliest settler traders and Newfoundland fishermen for introducing the Inuit to objectionable pastimes such as gambling, drinking and dancing. (In Lutz, *Musical Traditions of the Labrador Coast*)

Oral evidence, in the form of the personal experience narratives now being recorded, show how eagerly the Labadorians looked forward to the summer visits of the Newfoundlanders who were not only a form of living insurance but also an assurance that the countless harbours and islands would ring with music, song and dance when the hard work of fishing was done. The traditional Labrador fishery lives on in the hearts of those who went "on the Labrador", and of those who miss the visits enough to come up to Conception Bay for a reunion or to stop to talk to me, a researcher whose father fished down on the Labrador where his father had fished before.

One informant told me she had been anxious to meet me when she heard I was in Rigolet because she wondered whether she knew "my people". She and her friend told me how much they enjoyed the visits of Newfoundlanders in the summertime because the memory of the singing, the dancing, the card games and the company lasted through the isolation of winter. Although it is impossible to duplicate for you the expression in her eyes when she said this the sentiments articulated by her have been echoed by many in Labrador and Newfoundland.

> We'd miss that after they would go away, and the harbour would look so empty for another year.
>
> (Murphy 49, MUNFLA 86-013/C8625)

Acknowledgments

This paper is based on fieldwork done on the coast of Labrador, research in The Memorial University of Newfoundland Folklore and Language Archive (MUNFLA), and in the archives of *Them Days Magazine*, Happy Valley-Goose Bay, Labrador. Funding for fieldwork in Labrador was provided by the Institute of Social and Economic Research and by the Northern Scientific Training Program. An earlier version of this paper was read at the 1985 meeting of the Folklore Studies Association of Canada. This final version owes much to discussions with Lynn MacDonald, Susan Hart, Kathryn Kimiecik, Barbara Rieti and Philip Hiscock of the Department of Folklore of Memorial University. I would especially like to thank the people in Labrador who took the time to talk to me about their many and varied experiences.

References

Campbell, L. Sketches of Labrador life. Them Days Publications (1980):32. Originally published in The Evening Telegram newspaper as a series of letters to Rev. Arthur C. Waghorne giving some account of Labrador life. Lydia Campbell was seventy-five years old at the time of writing.

Davis, M. 1977. Sandwich Bay nurse. Them Days: Stories of Early Labrador. 2(4):44.

Ford, A. 1978. Skin boots for boats. Them Days: Stories of Early Labrador. 4(2):9.

Lutz, M.M. 1982. Musical traditions of the Labrador coast Innuit. Ottawa: National Museums of Canada, p. 10.

MUNFLA 75-257, pp. 9-10.

MUNFLA 86-013/C8675. This refers to tape number C8675 of my collection of fieldwork tapes on deposit at the Memorial University of Newfoundland Folklore and Language Archive under master accession number 86-013.

MUNFLA 86-013/C8621.

MUNFLA 86-013/C8625.

MUNFLA 86-013/C8629.

VALUING TRADITIONAL ACTIVITIES IN THE NORTHERN NATIVE ECONOMY: THE CASE OF OLD CROW, YUKON TERRITORY

Sheilagh C. Murphy

Department of Geography, The University of British Columbia, Vancouver, B.C. V6T 1W5

Level: Master's

Abstract

It is becoming increasingly apparent that existing methods for valuing production from the land in northern Canada are imperfect or inadequate. An examination of these methods reveals that they fail to deal with non-market values the land and its bounty hold for native northerners. In response to this problem a more comprehensive valuation method is explored.

Using data collected in the community of Old Crow, Yukon Territory, in 1960, 1973 and 1984 it is shown that comparing similar activities at different points in time is a very effective means of precipitating out the wide range of values which influence the pursuit of traditional activities. While this method does not quantify or rank the relative worth of these values, it is an important step in extending contemporary valuation methods to include native categories and perceptions of natural resources. Such a step is necessary if future government policies are to be successful in providing for the maintenance and growth of both the modern and traditional sectors of the northern economy.

Key words: Contemporary valuation methods, Old Crow, traditional activities, Native categories and perceptions.

Résumé

Il devient de plus en plus évident que les méthodes actuelles d'évaluation de la productivité des terres du Nord canadien sont imparfaites ou inadéquates. L'étude de ces méthodes montre qu'elles négligent les avantages non commerciaux procurés par ces terres, et leurs ressources abondantes pour les Autochtones. Pour remédier à ces lacunes, l'auteure envisage une méthode d'évaluation plus complète.

A l'aide des données recueillies en 1960, 1973 et 1984 dans la localité d'Old Crow, Yukon, l'étude montre que la comparaison d'activités semblables à différents moments constitue un moyen très efficace pour mettre en évidence toute la gamme des avantages qui poussent à la poursuite des activités traditionnelles. Bien que cette méthode ne permette pas de quantifier ces avantages ou de les ranger par ordre de valeur, elle fait un progrès important en incluant les catégories de ressources et leur perception par les Autochtones dans les techniques actuelles d'évaluation. Cette prise en compte est indispensable pour que les politiques de l'État permettent de maintenir et de développer les secteurs tant moderne que traditionnel de l'économie nordique.

Mots-clés: Méthodes actuelles d'évaluation, Old Crow, activités traditionnelles, perception et catégories autochtones.

Introduction

There is now increasing acceptance by the research community of facts and situations that the northern native people have always held to be true; namely, the importance of land-based renewable resources in their domestic economy. In particular, the paramount place that country food continues to hold even as the wage economy intrudes. Consequently, there has been increasing demand for a more balanced approach to development in the Canadian north; an approach emphasizing policies which provide for the maintenance and growth of both the modern and traditional sectors of the northern economy.

Unfortunately, a fundamental problem seems to be hindering the easy development of such policies. To date, no generally agreed upon method of measuring either the value of production from the land, or its exchange values has been found. Recent efforts have tended to employ conventional accounting systems which give only a partial and unsatisfactory picture of the value of traditional activities. These methods fail to recognize that the resource needs of native people which arise out of tradition or custom are just as real as those that rise from physical and economic want (Roots, 1981:250). Thus, in order for future policies to stimulate successfully both the modern and traditional sectors of the economy, a new method of valuation is required. The method chosen will have to account for the cultural, nutritional, psychological and political significance natural resources hold for the indigenous people; in addition to their economic importance.

The present study attempts to define such a method. Using data collected in Old Crow, Yukon Territory in 1960, 1973 and 1984, the paper develops a valuation method that focusses on precipitating out those 'values'[1] which have influenced the choices that native people have made about traditional pursuits, both past and present. By tracking attitudes and perceptions, as well as a group's activities through time, a better evaluation of renewable resources is achieved. This type of approach sharply contrasts with the current practice of defining the value of renewable resources numerically because it goes beyond merely analysing the quantifiable elements of native activities by also trying to understand a group's ethos.

Background

Any assessment of a contemporary native community, its people, and their relationship to the land and its bounty, would not be complete without some reference to their way of life, past and present.

The village of Old Crow, established in 1912, is situated on the Porcupine River in the northwest part of Yukon Territory. The people are Loucheux Indians of the Vunta and Tukkuth Kutchin tribes. In 1983 the population was approximately 236 people, of which 217 were either Indian or Métis.

Traditionally, the Kutchin lived in small nomadic family groups which moved throughout their lands in order to take advantage of the spring and fall migration of the Porcupine Caribou herd. Summers were spent at fishing camps along the riverbanks, while the winter months were spent in the hills following the caribou and capturing other game like moose or rabbit. Today the Porcupine herd is still the mainstay of the Old Crow people. Summers are often spent fishing and moose, rabbit, birds and muskrat continue to add variety to the people's diet.

The contact period for the Yukon Kutchin began with the penetration of the fur trade from Alaska in the late 1700's, and ended with the establishment of a fur trading post on the Porcupine River at the Alaska/Yukon border in 1904. During this time fur traders, missionaries, whalers, gold seekers and the police all acted as agents of change. Through their activities they introduced a way of life that was more sedentary, and which increasingly bound the Kutchin to the outside world. Despite this, the Kutchin continued to carry out most of the activities associated with more traditional times, with the exception of dispersal to traplines rather than hunting ranges during the winter months.

Between 1904 and 1950 the Kutchin of Old Crow continued to hunt, fish and trap, spending long periods of time out on the land and away from town. In spring, after the hunt, it became quite common for families to travel north to Old Crow Flats (the Flats) for muskrat season. This annual spring trek still takes place in Old Crow. It is a time to get out on the land and away from town; a time to enjoy the first days of spring.

The decline in fur prices in the 1950's and the opening of a school and nursing station in 1961 saw a change in the Kutchin seasonal round once again, as the majority of people took up permanent settlement in Old Crow. Several men began to take advantage of wage employment opportunities both in and out of town, and trapping, hunting and fishing were often carried out on a part-time basis from town.

Since that time, life has become far more complex with the introduction of such things as wage employment, government assistance, imported foods, outside schooling and television. The presence of these in the lives of the Old Crow people have expanded wants, aspirations and lifestyle choices. Nevertheless, the land and its bounty remain important to the way of life in Old Crow. The community's geographical location, close to resources and peripheral to industrial economic activity, has created a situation whereby residents have been able to continue practicing traditional pursuits without having to forfeit the amenities of town life.

Data and sample size

Data was collected using existing literature on both Old Crow and the research topic, and by administering a comprehensive questionnaire within the larger framework of an ethnographic interview during the summer of 1984. The questionnaire format was similar to the one used by Dr. J.K. Stager in Old Crow in 1973. Designed to elicit facts and the quantifiable elements of the people's activities and general life rhythm in Old Crow, the use of this questionnaire in 1984 provided a unique opportunity to determine how traditional activities had changed over time.

Seventy-five adults over the age of 20 were interviewed, representing 62 per cent of the adult population and 54 of the 70 households. Results were recorded according to age and household. Fortunately, because of the share ethic within the community, information on the amount of country food used by several of the households not interviewed was obtained through relatives and friends.

The proposed method

In order to get at the social 'values' associated with production, native attitudes and perceptions of resources, both past and present, need to be examined. This can be achieved by identifying:

1) those traditional activities a cultural group has *chosen* to preserve while undergoing complex social transformations;

2) the value *assigned* these activities by the people themselves: economic, cultural, historical and so forth;

and

3) the social relations of production[2] operative in a society which cause the 'value' assigned and activity to fluctuate over time.

Traditional activities in contemporary Old Crow

The mapping of land-use for different points in time is one way of identifying the place of traditional activities, past and present. Although not shown here, the data for Old Crow reveal that land-use has been operating over shrinking space since 1960, especially with respect to traplines. Hunting, fishing, trapping and woodcutting are now carried out in close proximity to town (within a day's travel time, round trip) and are usually done on a part-time basis.

Although spatial land-use has changed, harvest levels for most species have changed little in the last 20 years. Much of this is due to the fact that Old Crow enjoys a hinterland rich in resources which is easily accessible. Table 1 outlines game, fish and muskrat returns for select years between 1960 and 1984. Generally speaking, only the fish and caribou returns show any appreciable differences. The reduction in the amount of fish taken has occurred largely among dog salmon, and is attributable to the shift from dogteams to skidoos.

TABLE 1
Old Crow game, fish and muskrat returns
select years[1]

Species	1963 -64	1968 -69	1972 -73	1978 -79	1983 -84
Caribou	706	557	751	900	1,000
Moose	10	24	22	24	22
Bear	1	1	0	uknwn	uknwn
Geese[2]	15	25	uknwn	uknwn	uknwn
Ducks	155	50	342	313	255
Ptarmigan	196	27	uknwn	uknwn	uknwn
Rabbits	uknwn	uknwn	202	502	388
Fish	uknwn	14,936	10,895	8,588	6,246
Muskrats	14,000	9,461	13,725	15,277	11,416

Notes 1: Records are available for most years after 1960 but were not included due to space constraints.

2: Geese & Ptarmigan returns were often not available because informants who often hunted out of season did not want numbers known.

Sources: McSkimming, 1975:92; YTG Renewable Resources, Whitehorse; Field Data, 1984.

A very different case exists for caribou. Returns were relatively stable between 1963 and the mid 1970's. After this there was a steady increase perhaps due to an increase in the adult population or the occurrence of freezers in every household which has increased the amount of meat that can be stored year round. There is also the reality that the people now possess the means to capture large quantities of food in a short time, and trips out on the land are for the explicit purpose of hunting a particular species.

One thing the harvest figures do not show is participation levels. These also indicate the place of traditional activities in the lives of native people. In terms of hunting game, participation rates have remained constant over the past 20 years, while they have decreased for both fish and muskrat hunting (ratting). The reduced number of dogs explains the lower interest in fishing. Explanations for the decline in ratting participation may be: 1) children are no longer released from school; 2) many adults hold permanent jobs and cannot justify a trip to the Flats; 3) many young people find that ratting returns do not justify the effort and cost incurred; and 4) going to the Flats has become a costly endeavour and one many families cannot afford every year. In spite of this, an examination of productivity per camp revealed that production per camp has increased thereby keeping final production figures relatively stable. This increased productivity may be due to the reality that most rats are now shot instead of trapped. Less time is required, the work is easier, and returns are usually quite high.

As with game, fur returns have remained quite stable over the past 20 years. Fluctuations can be attributed to changes in either species availability or trapping effort. A good indication of changes in trapping effort is productivity. The data reveal that catch per kilometer and catch per trapper has decreased since 1960; a combination of declining fur prices and decreased effort. However, since 1973 catch per trapper has levelled off. Perhaps production levels have reached an equilibrium point; the same men trapping in 1970 are the same ones trapping today. Whether this trend will continue depends on the interest of young people. Currently, only a few men under the age of 35 possess both the interest and skills necessary to make them successful on the trapline.

In addition to the above, woodcutting and handicrafts also continue to play an important role in the household economy. The use of local logs for heating saves the community thousands of dollars annually and generates personal income through its sale to the school and Band wood program. Similarily handicrafts are made and sold through the Old Crow Arts and Crafts Co-op, fulfilling a very important employment function, given that wage employment opportunities for women are few.

The traditional activities practiced in contemporary Old Crow have been identified. Although some activities have either been abandoned or become anomalous over the years, others have been consciously preserved, or even intensified, through choices made by the people themselves. All remaining activities have undergone change, however the fact that they are still practiced is, in itself, an indication of 'value'.

'Value' assigned to traditional activities by the Old Crow people

Research has proven that traditional activities hold considerable economic value for most northern societies (see for example: Feit, 1979; Nowak, 1975; Stager, 1974; Usher, 1971; and Van Stone, 1960). Much of this stems from the fact that wage employment opportunities are still not great enough in most communities to provide the sole economic base. Old Crow does not escape this condition. The income generated from traditional activities enables most households to lead a modern lifestyle, with an adequate standard of living.

Table 2 shows quite clearly the significant economic contribution traditional activities make to the Old Crow economy. Values for country food were imputed using imported meat prices. Some 36 per cent of all income generated in Old Crow in 1983 came from the traditional sector, with 89 per cent of this generated through the use of country food and wood heat. It seems that because all Old Crow households derive income from both the modern and traditional sectors, it may in fact be the *material security* found in the combination of cash and subsistence resources which forms the 'value' of most significance here, instead of more obvious economic value.

Subsistence activities hold other 'values' for the people of Old Crow. The sharing of food, equipment, and labour fosters interdependence among Old Crow households, and

TABLE 2
Income calculations for Old Crow, 1983

ITEM	Total Value[1] (field data)	Average Value per hshld (51)	Estimated Total Value for Community (70)
Wood Heat[2] (avg crds/hshld= 11.5	$ 223,273.75	$ 4,651.54	$ 325,607.55
Country food[3]	373,311.58	7,777.32	544,412.40
Fur Harvest	71,260.58	1,397.26	97,808.20
Handicrafts	7,000.00	137.32	9,607.84
sub total	$ 674,845.91	$ 13,963.37	$ 977,435.99
Wages[4]	$ 499,765.00	$ 10,633.32	$ 744,332.40
Trans. Payments[5]	169,682.26	3,610.26	249,470.07[6]
Other Gov't contributions	530,692.23[7]	10,405.73	728,401.00
total	$1,874,985.40	$38,612.68	$2,699,639.44

% Income from:	Field Data (51)	Estimated Total (70)
Traditional Sector	36%	36.2%
Wages	26.6%	27.5%
Government Sources	37.3%	36.2%

Notes 1: Field data was based on interviews with 51 households out of 70 (72.8%)
2: Wood Heat was derived from the cost of replacing 1 cord of dry spruce with heating oil; $403.75 (EMR, Ottawa, 1985 and W. Attwood, DIAND, Whitehorse)
3: Country food totals are based on 48 households and the average adjusted accordingly.
4 & 5: The same applies here as in note 3 (48 not 51 households).
6: The transfer payment total here is based on calculations for the entire community from information from Health and Welfare and is not the extension of the average figure.
7: The data here was derived from the average figure, which was derived from the total figure, this figure came from Band records.

Source: field data and Health and Welfare Canada

in turn binds the people together socially. The social products generated by this help to reinforce community solidarity at a time when modern transportation and communications, the increased availability of cash and liquor, and an increase in alcohol related crimes serve to undermine the quality of life in town.

Getting out on the land and away from town is another very important benefit associated with traditional pursuits, and is best displayed by the annual trek to the Flats in spring, and the fall caribou hunt. Ratting, hunting and fishing also present families with the opportunity to teach children the basic skills necessary to successfully carry out various traditional activities. Whether current efforts to pass on traditional skills to children will result in the continuation of the traditional economy, however modified, will depend on a wide variety of factors, including the range of lifestyle choices available to these children as young adults.

There are several other social 'values' operative in Old Crow, unfortunately, accounting for such things as the cultural 'need' to eat caribou or the psychological satisfaction gained from a successful hunt cannot easily be accomplished when one is not a member of the cultural group. In the case of Old Crow it was simply acknowledged that there were as many or more social benefits as there were adults. All were important to the people and were seen as the rewards of living a life close to the land.

The social relations of production

This third and final category of data deals with the identification of the 'values', beliefs and social forms existent within a group that play a formative role in structuring the processes of productive activity. Producing for use rather than exchange value, community feasts, distributing products according to socially defined rules, and using a barter rather than a cash system were all community strategies (social forms) created by the Old Crow people in an effort to preserve their relationship with the land and its bounty.

At the household level very different social relations of production were created. Because of the lack of economic uniformity, households were found to pursue traditional activities for different reasons using different strategies. These strategies were usually carefully thought out and were based on such things as income, family membership and kinship ties.

For these households where the hunter also worked full-time, income was often invested in efficient, less demanding subsistence technology which enabled the hunter to offset the reduced amount of time he could spend engaged in traditional activities. Other households pooled their labour in order to take advantage of several production opportunities without forfeiting wage income. It was not unusual for family members, who were either unemployed or shift workers, to do most of the hunting, so that those who were working full-time or incapable of hunting were provided for. Similarly, several women often formed one summer fish camp, pooling labour and equipment, with the products being distributed equally. This allowed two or three families to fish, who on their own might not have been able to afford such an activity.

A similar pooling of household labour and equipment characterized many spring ratting camps. For several families a trip to the Flats represented an expensive undertaking, especially if the principal wage earner had to leave his job. Hence several families would combine resources, leaving the wage earners in town so that income was being made both in town and at the Flats.

Directly connected to these production strategies were the 'values' and beliefs associated with certain resources. Both Canadian and Alaskan researchers have found that it is often because of the persistence of certain 'values' and beliefs that modern productive activity still occurs. In Old Crow these ranged from economic and nutritional to social and psychological, depending on both personal and household characteristics. For those households, where money income was scarce for example, the income in kind generated through hunting and fishing, was usually the most important 'value'. This is not to say that other 'values' commonly associated with harvesting did not exist. Rather, the economic 'value' of production was merely more prominent. Over time, if money income were to increase, other less visible values would, in all likelihood, increase in importance. Given this, it is easy to see why valuation research should focus on identifying the *range* of values that exist for a group, instead of one specific 'value'.

In the previous pages the native attitudes and perceptions towards the land operative in Old Crow have been identified. Clearly, the combining of historical and recent data has shown that numerous 'values' exist in connection with resource use in the community. If no comprehensive historical record had existed, a similar conclusion could have been reached using only current data. By comparing the activities of different aged informants; analysing the time

allotted different activities; comparing activities to a similar community; or mapping land use of both young and old, one could still identify the 'values'. What is important is to in some way include the social realm of production, including the possibility of changing values through time. As long as an activity is still practiced it has value.

Conclusions

The research has shown that only by going beyond numerical analysis can the 'values' truly important to a group be identified. By searching for native attitudes and perceptions towards the land the social realm of production is introduced and gives a much needed additional dimension to contemporary valuation schemes. The data collected on Old Crow indicate that the people 'value' their way of life for several reasons, and that they have a continuing bond with the land despite the increasing intrusion of the outside market place.

Unfortunately because so many 'values' existed in Old Crow, some never identified, a comprehensive 'value' acceptable to all interested parties could not be identified. This raises the question, can we as researchers actually find a comprehensive 'value' for a way of life which falls outside our life experiences? Perhaps researchers and policy makers will just have to accept that native northerners 'value' their way of life and because the traditional sector of the northern economy is still very much alive, it deserves policies which will ensure its maintenance and growth.

Footnotes

1 For the purposes of this paper 'value' means that which is worthy or desirable of esteem for its own sake; thing or quality having intrinsic worth. Conversely, value means the worth of a good in money or other numerical terms at a certain point in time.

2 The social relations of production: the social organization of productivity and the values and beliefs which serve to perpetuate it (Usher, 1981:57).

References

Feit, Harvey A. 'The future of hunters within nation-states: anthropology and the James Bay Cree' expansion of a paper presented at the Conference on Hunters and Gatherers. Paris, June 27-30. 1979.

Kemp, W.B. 'The flow of energy in a hunting society.' Scientific American. (224:3) 1971 pp. 104-116.

Lonner, Thomas D. 'Subsistence as an economic system in Alaska: theoretical observations and management implications.' Langdon, Steve J. Contemporary Subsistence Economies of Alaska. Department of Fish and Game, Alaska. Division of Subsistence. Technical Paper No. 67. Juneau, 1981 pp. 43-74.

McSkimming, R.J. Territory, Territoriality, And Cultural Change In An Indigenous Society: Old Crow, Yukon Territory. Unpublished M.A. Thesis, Department of Geography, The University of British Columbia, Vancouver. May, 1975.

Muller-Wille, Ludger, 'Cost analysis of modern hunting, among the Inuit of the Canadian Central Arctic.' Polar Geography. Vol. II. No. 2. April-June. 1978 pp. 100-114.

Nowak, Michael. 'The economics of native subsistence activities in a village of southwestern Alaska.' Arctic vol. 30. No. 4. Dec. 1977 pp. 225-233.

Roots, E.F. 'Can we talk our way into a better northern resource management and economy?' Freeman, Milton, M.R. (ed) Proceedings First International Symposium on Renewable Resources and the Economy of the North. Banff, Alberta. May, 1981. ACUNS, Ottawa. 1981 pp. 249-259.

Stager, J.K. Old Crow, Y.T. And The Proposed Northern Gas Pipeline. Prepared for: the Environmental Social Program, Northern Pipelines. June, 1974. Task Force on Northern Oil Development. Report No. 74-21.

Usher, Peter J. The Bankslanders: Economy and Ecology of A Frontier Trapping Community. 3 vols. Dept. of Indian Affairs and Northern Development. Northern Science Research Group. Ottawa. 1971. NSRG 72-2.

_____ 'Sustenance or recreation? The future of native wildlife harvesting in Northern Canada. Freeman, Milton M.R. (ed) Proceedings: First International Symposium on Renewable Resources and the Economy of the North. ACUNS. Ottawa. 1981. pp. 56-71.

Van Stone, James W. 'A successful combination of subsistence and wage economies at the village level.' Economic Development and Cultural Change. The University of Chicago. Vol. 8. No. 2. January, 1960. pp. 174-191.

COOPERATIVE PLANNING AND MANAGEMENT OF NATIONAL PARKS AND NATIONAL WILDLIFE AREAS IN THE NORTHWEST TERRITORIES

David A. Neufeld

School of Urban and Regional Planning, University of Waterloo, Waterloo, Ontario N2L 3G1

Now, Legislative Research Service, Legislative Library, Research and Information Services, Queen's Park, Toronto, M7A 1A2

Level: Master's

Abstract

The study describes, analyzes and compares interorganizational cooperation in planning and managing recent national park and national wildlife area initiatives in the Northwest Territories. Based on a review of the literature, a conceptual framework for interorganizational cooperation is designed. The seven components of the framework are: organizational motivation, intervention mechanisms, coordinating mechanisms, role structure, resource and communication flows, conflicts, and outcome. The selected northern case studies are the Polar Bear Pass National Wildlife Area and the proposed Ellesmere Island National Park Reserve. Recommendations for the Polar Bear Pass case include: 1) Development of increased policy support for cooperation by the Canadian Wildlife Service and the Department of Renewable Resources. 2) Allocation of greater authority to the Northwest Territories Habitat Working Group to formulate interagency agreements. 3) Allocation

of the drafting area management plan to the Area Advisory Committee. 4) Initiation of communication with the community of Resolute Bay. 5) Territorial representation on the Area Management Authority.

Recommendations for the Ellesmere case include: 1) Amendments to the National Parks Act to provide for greater interorganizational cooperation. 2) Native representation on the Parks Canada Consultative Committee. 3) Increased use of the Parks Canada Yellowknife office as the primary contact for the territorial government. 4) Development of a master agreement for national park establishment with the territorial government.

Key words: Interorganizational cooperation, national wildlife area, national park, native, Northwest Territories.

Résumé

L'étude décrit, analyse et compare la collaboration entre les organismes officiels en matière de planification et de gestion des parcs nationaux de création récente et d'initiatives nationales concernant les réserves fauniques des Territoires du Nord-Ouest. L'auteur, en se fondant sur une analyse de la littérature technique, élabore un cadre théorique de collaboration entre ces organismes. Les études de cas nordiques choisies ont concerné la Réserve nationale Polar Bear Pass et la Réserve nationale proposée pour l'île d'Ellesmere.

Les recommandations concernant la Réserve Polar Bear Pass sont, entre autres: 1) Fourniture d'un plus large soutien de principe, par le Service canadien de la faune et le ministère des Ressources renouvelables, à cette collaboration; 2) attribution d'un plus large mandat au Groupe de travail sur les habitats des Territoires du Nord-Ouest pour élaborer des accords inter-organismes; 3) élaboration du plan de gestion régional par le Comité consultatif régional; 4) établissement de communications avec la population de Resolute Bay; 5) représentation territoriale au sein du Service régional de gestion.

Les recommandations concernant la Réserve de l'île d'Ellesmere sont, entre autres: 1) Modifications à la *Loi sur les parcs nationaux*, en vue de développer la collaboration entre organismes officiels; 2) représentation autochtone au sein du Comité consultatif de Parcs Canada; 3) plus large utilisation des bureaux de Parcs Canada à Yellowknife comme principal point de contact par le gouvernement territorial; 4) élaboration d'un accord-cadre avec le gouvernement territorial pour la création d'un parc national.

Mots-clés: Collaboration entre organismes officiels, réserve faunique national, Autochtones, Territoires du Nord-Ouest.

Introduction

Canadian lands north of the 60th parallel are receiving significant attention from different orders of government, development interests and native groups for their resource potential and associated socio-economic opportunities. At present the federal government retains control/ownership over non-renewable resources, forestry, commercial fishing, water rights, road construction, and migratory birds, as well as judicial and health care functions. The Government of the Northwest Territories currently has direct control over small areas of land in and around communities, and has various land-related responsibilities including wildlife management, archaeological sites, territorial parks and agriculture. In recent years it has continued to press for increased control over territorial land and resources. One specific expression has been pressure for greater involvement in planning and managing national parks. (N.W.T., Dept. Economic Development and Tourism, 1981).

Through the native claims process northern natives are securing rights of access to, and a measure of control over, land areas and natural resources. Through their final claim settlement, the Inuvialuit of the Western Arctic gained direct participation in the planning and management of the national park in the Yukon North Slope and the region's wildlife resources (Western Arctic claim, 1984). The Inuit of the eastern and central Arctic have gained agreements-in-principle with the federal government relating to wildlife management as well as two sub-agreements concerning national parks and conservation areas in their claim area (Wildlife provisions, 1981; Conservation areas provisions, 1983; National park provisions, 1983).

It is in the context of increased development pressures, evolution toward responsible government and comprehensive native claims, that the federal government has recognized the need for creating a system of conservation areas to introduce a balance between resource development and wildlife/wilderness conservation in Canada's north (Gillespie and McComb, 1984). It is clear that the long term success of federal northern conservation programs will depend largely on the recognition of the interdependencies between the different levels of government and native groups, and the extent to which cooperation among these three groups can be achieved.

In light of the above, the goal of this research was to describe, analyze and compare cooperation between the federal government, the territorial government, and local native groups in planning and managing recent national park and national wildlife area initiatives in the Northwest territories. For this study the two case studies selected for analysis were the Polar Bear Pass National Wildlife Area on Bathurst Island (Figure 1) and the proposed Ellesmere Island National Park Reserve on Ellesmere Island (Figure 2). Polar Bear Pass was the only national wildlife area at an advanced planning stage in the Northwest Territories, while the Ellesmere case exemplified the most extensive cooperation to date between Parks Canada, the territorial government and local natives.

In both cases the core federal and territorial government actors and core, or supporting, native actors were the focus of analysis (as per Fischer and Keith, 1977). In the Polar Bear Pass case the selected actor groups included the Canadian Wildlife Service, the territorial Department of Renewable Resources, and representatives of the community of Resolute Bay. In the Ellesmere case the actor groups included Parks Canada, the territorial Department of Economic Development and Tourism, and representatives of the community of Grise Fiord.

Conceptual framework

The approach adopted was diagnostic and evaluative. A conceptual framework of interorganizational cooperation was designed to describe and analyze the selected cases systematically. It represents a synthesis of the major concepts addressed in the literature on interorganizational relations.

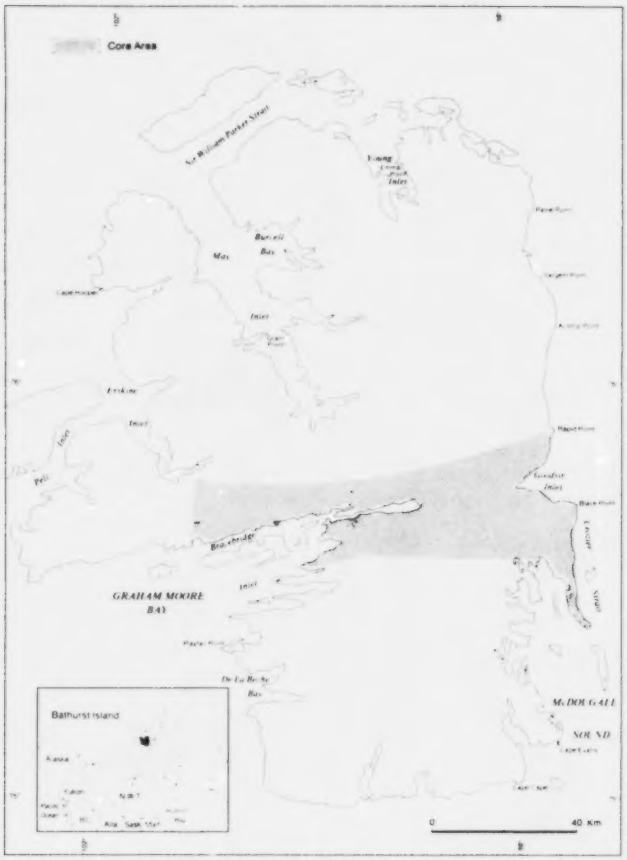


Figure 1. Polar Bear Pass National Wildlife Area

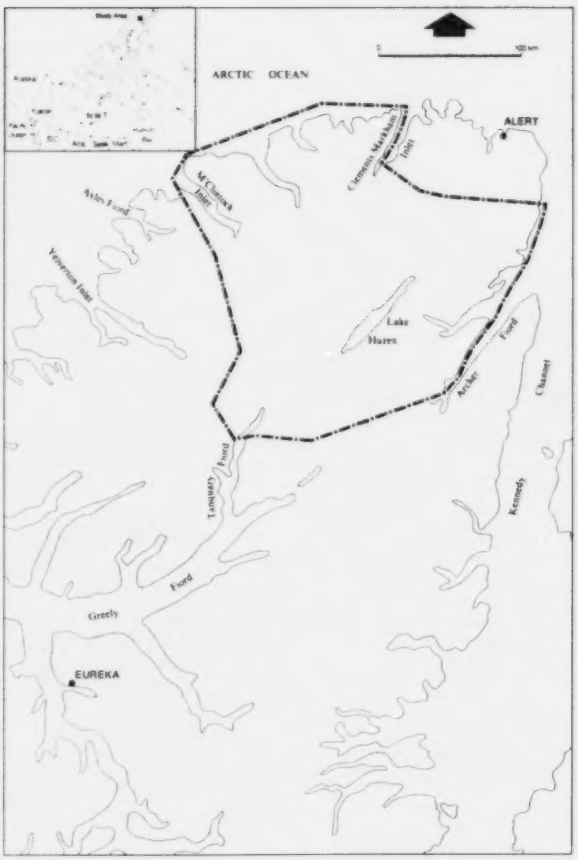


Figure 2. Proposed Ellesmere Island National Park Reserve

The literature on interorganizational relations is characterized by its lack of cohesiveness, variously defined terms, and multiple foci. Much research in this field has focussed on the human service sector, including health care, welfare, employment and manpower training systems (Morrissey et al., 1982; Neghand; 1975; Rogers and Whetten, 1982). A major historic impetus was the recognition of the need to improve the quality of government services in a fragmented, uncoordinated system of specialized agencies (Hanf, 1977).

Few researchers have attempted to synthesize the major concepts associated with interorganizational cooperation into an analytical framework. Fewer still have applied a clearly defined framework to cooperatively planned and managed protected areas (Gardner and Nelson, 1980). Thus the framework designed in this study is necessarily a preliminary approximation of interorganizational cooperation.

Table 1 presents a cooperation assessment framework in which interorganizational cooperation consists of seven components: organizational motivation, intervention mechanisms, coordinating mechanisms, role structure, resource and communication flows, conflicts, and outcome. Each component consists of one or more variables, which have been operationalized in a set of criteria. For a more extensive treatment of the framework and the cases, the reader is referred to Neufeld (1985).

Organizational motivation

Although the unit of analysis in interorganizational research is the set of relations between groups and not individual organizations themselves, cooperation is rooted in the participants. Thus characteristics which substantially influence an organization's involvement in a cooperative effort must be accounted for. One important basis for cooperation is the presence of compatible goals among participating organizations. The degree to which organizational goals are perceived to be compatible will facilitate cooperation (Halpert, 1982; Reid, 1964). Organizational statements and procedures which explicitly promote cooperation are also important for the formation and development of cooperative endeavours (Ideli, 1973; Whetten and Bozeman, 1981). Successful cooperation also requires that operational and administrative staff favour cooperating with other agencies (Halpert, 1982; Rogers and Maas, 1977; Whetten, 1977).

Intervention mechanisms

Intervention in the interorganizational environment is a critical step in the formation of a cooperative system (Walton, 1972). It can take the form of legislation, contractual agreements, guidelines, revised goals or coalition formation (Tuite, 1972). Intervention can occur at the general level to provide a broad framework for cooperation as well

TABLE 1
Cooperation Assessment Framework

COMPONENT COOPERATION ASSESSMENT	VARIABLE(S)	CRITERION(A)
Organizational Motivation	1. Organizational Objectives 2. Cooperative Policies 3. Personnel Motivation	* Goal Compatibility * Degree of Policy Support * Degree of Personnel Support
Intervention Mechanisms	1. Participants	* Representation
Coordinating Mechanisms	1. Membership 2. Functions 3. Authority	* Inclusiveness * Comprehensiveness * Degree of Authority
Role Structure	1. Role Distribution 2. Decision-Making Distribution	* Clarity * Satisfaction * Degree of Collective Decision Making
Resource and Communication Flows	1. Commitments 2. Communication Network	* Resource Agreement * Communication Effectiveness
Conflicts	1. Type	* Resolution Quality
Outcome	1. Organization Goal Achievement 2. Collective Goal Achievement	* Degree of Organizational Achievement * Degree of Collective Achievement

as at the site level to help delineate specific roles and responsibilities. At both levels intervention often provides the basis for establishing some type of administrative structure (Koenig, 1981; Reid, 1964; Van de Ven and Ferry, 1980). Accordingly it is important that key organizations or groups are specified as participants in legislation or agreements.

Coordinating mechanisms

A formal mechanism for mediating relations is a coordinating body. It can provide a focus for responsibility, address potential conflicts and facilitate joint action (Mott, 1968). To play an integral role in interagency cooperation a coordinating mechanism should perform three major functions:

*regulation — Develop rules, procedures and policies for (inter)action.

*infrastructure support — Coordinate the provision and exchange of resources.

*appreciation — Act as a forum for the exchange of perceptions, attitudes and values regarding desirable courses of action. (Trist, 1982)

The ability of a coordinating body to make binding decisions for the participating agencies will increase its importance and value. Key organizations should be represented on coordinating bodies at general and site-specific levels.

Role structure

Organizational roles and responsibilities in a cooperative undertaking should be clearly identified and accepted by participating agencies (Ideli, 1973; Jewell and Reitz, 1981). Role clarity avoids unnecessary confusion and duplication of effort while role acceptance facilitates performance and positive attitudes toward the cooperative venture.

The focus of control over decision making is fundamental to cooperation. The degree to which organizations perceive that they are effectively involved in the decisions taken is positively related to their role satisfaction and sense of organizational achievement

Resource and communication flows

The involvement of organizations in a network requires contribution of some of their resources to the system (Warren, 1972). Because many organizations do not possess all the resources they require to attain their goals they must seek out other agencies to exchange or pool resources (Reid, 1964). Two common resources linking organizations in a network are money and personnel. Fiscal linkages include joint budgeting and funding, fund transfers and service purchases. Personnel linkages include use of staff, consolidated personnel administration and staff transfers and co-location (Mulford and Rogers, 1982). The ability of organizations to agree on respective resource commitments is fundamental to any cooperative venture.

Effective communication between organizations is also essential for developing interorganizational relationships (Hall *et al.*, 1978; Ideli, 1973). It is the link between organizations which enables the exchange of information, facts, feelings, and impressions regarding purposes, ends and means for collaboration (Van de Ven and Ferry, 1980).

Conflicts

While interorganizational cooperation presupposes a certain degree of common interest, disagreements among organizations in the process of establishing and implementing cooperative arrangements can be expected (Hanf, 1977). A major source of conflict is disagreement regarding mutual and collective goals, and appropriate means to achieve them (Halpert, 1982; Molnar and Rogers, 1982). Another source of conflict centers around organizational boundaries of responsibility and respective roles in the interorganizational network (Akinbode and Clark, 1975; Walton et al., 1969).

Disagreement can also occur over technical issues such as the adequacy of information and its interpretation (Mott, 1968). For cooperation to be successful conflicts must be resolved to the satisfaction of the disputing parties.

Outcome

As previously suggested, interorganizational cooperation is the product of groups or agencies pursuing individual and collective interests. One measure of success is the extent to which organizations perceive the cooperative relationship to be worthwhile and productive for achieving their objectives (Van de Venn and Ferry, 1980). Finally, the ability of the cooperative network to achieve the basic goal to which cooperation was directed is a critical indicator of its ultimate effectiveness (Mott, 1968).

Polar Bear Pass National Wildlife Area

Polar Bear Pass is an area of 2,634 square kilometres, characterized by lowlands, with numerous wetlands and streams lying between ridges of folded bedrock. It has the highest diversity of bird species of any comparably sized area in the high Arctic and is an important calving and wintering ground for muskoxen. Peary caribou also traverse the area on a seasonal basis.

In 1975 the area was noted by the Interdepartmental Working Group on International Biological Programme Ecological Sites and three years later it was withdrawn from further disposition under the federal Territorial Lands Act. Subsequent to public hearings it was announced that the site would become a national wildlife area under the Canada Wildlife Act, and that a wildlife management agreement was to be signed by the two levels of government. Also an area advisory committee on site management was to be established (Indian and Northern Affairs, 1983). At the termination of the present study intermittent negotiations concerning the management agreement and a more general memorandum of understanding were continuing.

Organizational motivation

The goals of conservation and long term use of the wildlife of Polar Bear Pass were shared by the Canadian Wildlife Service, the Territorial Department of Renewable Resources, and the residents of the nearest community of Resolute Bay. The federal participant was primarily interested in migratory birds while the territorial participant was primarily interested in mammals. All three parties upheld the principle of native harvesting rights.

The Canadian Wildlife Service had no divisional policies or procedures for involving other organizations in planning and managing wildlife areas. The Department of which it was a part had general statements on cooperation.

The Territorial Department of Renewable Resources had no formal policies which made reference to interorganizational cooperation. In contrast, there was strong native policy support for cooperation under the Wildlife Provisions agreement-in-principle and the Conservation Areas Provisions sub-agreement of the Tungavik Federation of Nunavut claim.

Personnel support for cooperative planning and management was high among all three of the aforementioned groups. All recognized the need for cooperation in national wildlife areas of mutual interest and responsibility, and the organizational benefits derived from cooperation.

Intervention mechanisms

The Canada Wildlife Act provided for the development of agreements with government agencies, and other groups or persons for their participation in wildlife research, conservation, interpretation, and administration of wildlife areas. A general agreement being negotiated in this case was a Memorandum of Understanding between the two government actors concerning wildlife conservation areas. Its major limitation was its failure to specify native groups as participating agencies in planning and managing wildlife areas. The draft management agreement for Polar Bear Pass named all three groups as participants in the area's management.

Coordinating mechanisms

The general coordinating mechanism was the Northwest Territories Habitat Working Group. Its contribution to interagency cooperation was limited by its lack of ability to make binding decisions. It performed solely as a forum for the exchange of information and ideas. Further it had no native representation.

At the site level, the signatories to the management agreement and an area advisory committee will form a coordinating mechanism. However planning and management decisions which the signatories make will be subject to approval by the area's management authority (federal representative). Natives were not named as signatories to the management agreement.

The area advisory committee will have representation from all three parties. However its vague role of guiding and reviewing drafted area management plans, and lack of decision making authority, will limit its function.

Role structure

The decision to establish the wildlife area was made by the federal Minister of Indian and Northern Affairs. However, it was a collective process to the extent that the territorial Department of Renewable Resources and residents of Resolute Bay participated in the Interdepartmental Working Group on IBP Ecological Sites and the public hearings on the site, respectively.

The proposed decision making structure for planning and managing the area is collective, however the various management functions remain to be assigned. The role satisfaction of the Department of Renewable Resources was tempered by its broader interests in gaining responsibility for, and control over, conservation areas wherever possible. Native role satisfaction will depend on the extent to which they perceive themselves as having an effective role in making management decisions for the area.

Resource and communication flows

Resource commitments by the three parties for managing the area were not determined at the termination of this study. Communication flows between the Canadian Wildlife Service and the Department of Renewable Resources were stated by both to have provided effective exchange of information and opinions. In contrast, communication effectiveness between the Canadian Wildlife Service and the residents of Resolute Bay was non-existent, as there was virtually no exchange of information or ideas between them.

Conflict

At the termination of this study the previous conflict over the respective jurisdiction of the Canadian Wildlife Service and the Department of Renewable Resources at the site level was resolved to both parties' satisfaction. However, the quality of conflict resolution was reduced by territorial concern regarding federal control over subsequent wildlife areas. No conflicts between the residents of Resolute Bay and the government actors were reported.

Outcome

In terms of achieving organizational objectives, the Department of Renewable Resources' consistent interest in gaining responsibility and authority for administration of conservation areas in the Northwest Territories qualified their perceived success in the Polar Bear Pass case. Native satisfaction will depend on gaining access to the area's wildlife and on having a direct role in decision making.

Collective achievement of cooperation for Polar Bear Pass was moderate. Representatives from both government actor groups stated that progress had been made toward finalizing the outstanding general memorandum of understanding for wildlife conservation areas and the management agreement for Polar Bear Pass. However the delays were attributed to the ever present question of the relative jurisdiction of the two agencies over wildlife and wildlife areas in the Northwest Territories.

Ellesmere Island National Park Reserve

The proposed Ellesmere Island National Park Reserve of 39,500 square kilometers is dominated by glaciers and rugged mountains, with some of the highest peaks in eastern North America. The largest lake north of the Arctic Circle is found in the area. Lands surrounding Lake Hazen support small concentrations of muskoxen, Arctic hare, Peary caribou, polar bears, wolves, and Arctic fox. Inuit archaeological sites and remains of early European travellers are also found in the area.

In 1978, the land area which would eventually become the proposed park was identified by Parks Canada as part of a Natural Area of Canadian Significance. A year later Parks Canada began meeting with residents of the nearest community of Grise Fiord regarding the proposed park. Regular meetings were continuing at the termination of the present study. In 1981 discussions with the territorial government concerning a memorandum for the park's establishment began. A year later the memorandum was signed between Parks Canada and the territorial Department of Economic Development and Tourism, and the land withdrawn under the federal Territorial Lands Act. Parks Canada and the territorial government have now signed a final agreement.

Organizational motivation

Parks Canada staff and the territorial Department of Economic Development and Tourism stated there was broad agreement on goals. The primary interest of the territorial agency in economic development did not pose a major threat to Parks Canada's preservation objective because low visitation levels were anticipated for the park. Local native primary interests in increased community tourism and employment opportunities associated with the park were compatible with those of Parks Canada.

Parks Canada policy specifically promoted cooperation with territorial governments and native groups. In addition the agency had draft guidelines for native involvement in national park planning and management. The Department of Economic Development and Tourism had approved principles outlining territorial and native involvement in the establishment, planning and management of national parks. Native policy support was derived from the National Park Provisions sub-agreement of the Tungavik Federation of Nunavut claim.

Administrative and operational staff from the government agencies all acknowledged the importance and necessity of cooperation on national parks. Residents of Grise Fiord expressed interest in the benefits derived from the park's establishment.

Intervention mechanisms

The National Parks Act, under which the park would be established, fails to mandate cooperation with other organizations except through consultation. However, a general agreement for park selection and establishment was signed between Parks Canada and the Department of Economic Development and Tourism in 1981. Its major limitation was failure to identify native groups as participants in the process. At the site level a memorandum of understanding for the establishment of Ellesmere Island National Park was signed by the government agencies in 1982. In this agreement native people were named as participants in the process. Further to this, in 1983 Parks Canada released planning and management principles for the park which discussed territorial and local resident involvements.

Coordinating mechanisms

At the general level the Parks Canada-Government of the Northwest Territories Consultative Committee facilitated interagency cooperation. It had the authority to develop cooperative agreements and undertake collective action as well as coordinate fiscal and personnel resources. Its major limitation was lack of native representation.

At the local level the Grise Fiord Advisory Committee, consisting of local residents, performed solely an appreciative function. It lacked decision making authority and was solely a forum for expressing opinions to Parks Canada.

Role structure

The decision to propose the park was a highly cooperative process, which required ratification by the territorial government and local (native) residents. However after the park is formally established the territorial government and native representatives will perform largely a consultative function in the planning and management of the park.

Throughout the establishment process the territorial and native participants expressed a high degree of satisfaction with their involvement. Continued satisfaction will depend on the extent to which both groups perceive that their respective concerns directly influence the decisions taken in planning and managing the park. The local advisory committee is to become involved in management decisions concerning matters of joint interest with Parks Canada. However the form this will take is not clearly specified. The opportunity for local residents to contract for the development and maintenance of park facilities and visitor services is clearly stated in the park principles. Also, two residents were being trained as junior wardens for the park.

Resource and communication flows

Since Parks Canada will provide all the fiscal resources required to plan and manage the park, interagency resource commitments were not an issue. Parks Canada and the residents of Grise Fiord agreed that the community would provide a labour pool for construction requirements and junior park wardens.

The effectiveness of communication between Parks Canada and the Department of Economic Development and Tourism was reduced by the necessity of the latter to split its communication with Parks Canada between district, regional and head offices. The ongoing exchange of information and ideas between Parks Canada and the residents of Grise Fiord facilitated the latter's cooperation and support of the park.

Conflict

In the early discussions about the park, the government actions differed in their respective views of desirable levels of park visitation and support services. Also there was disagreement over joint control of archaeological work in the park. Both issues were resolved through internal organizational compromise and consensus reached at the Assistant Deputy Minister level through the Parks Canada-Northwest Territories Consultative Committee.

No conflicts between Parks Canada or the residents of Grise Fiord were reported by either group.

Outcome

Representatives of the Department of Economic Development and Tourism stated that they found their involvement to be worthwhile and productive. Although the extent of tourist promotion and control over archaeology was less than originally envisioned, they agreed to a compromise. Native goals of economic development and employment were to be realized when the park became operational.

All groups stated that progress had been made toward achieving the establishment of the park. However it was acknowledged that the process was taking longer than originally envisioned. One reason identified was the need to proceed at a pace which the local native population could accept. A second reason was the fact that a new initiative was taken to develop an agreement for establishing a national park which the territorial government would co-sign, and local natives would ratify.

Recommendations

Based on the analysis summarized above, the following recommendations for the two cases were made.

Polar Bear Pass

* The Canadian Wildlife Service and the Department of Renewable Resources should develop formal policies supporting cooperative planning and management of wildlife areas of mutual interest.
* The Northwest Territories Habitat Working Group should be given authority to formulate interagency agreements and coordinate the provision of resources.
* The area advisory committee for Polar Bear Pass should be given the authority to develop an area management plan.
* The Canadian Wildlife Service should initiate communication with the residents of Resolute Bay regarding progress with the management agreement, etc.
* The area management authority should have representation from the Department of Renewable Resources.

Ellesmere Island National Park Reserve

* The National Parks Act should be amended to provide for sharing of planning and management functions with other groups or organizations.
* The Parks Canada Consultative Committee should have native representation.
* Parks Canada should increase the use of its district office as the primary contact for the territorial government on all park-related matters.
* A master agreement should be developed by Parks Canada and the territorial government outlining the general terms which both agree are basic to all national parks in the Northwest Territories.

References

Aitken, M., R. Dewar, N. Ditomaso, J. Hage, G. Zeitz. 1975. Coordinating human services. San Francisco: Jossey-Bass Publishers.

Akinbode and Clark. Analyzing interorganizational relationships. Human Relations 29:102–121.

Conservation areas provisions of an agreement-in-principle. 1983. Ottawa: Tungavik Federation of Nunavut. August 23.

Fischer, D.W., and R.F. Keith. 1977. Assessing the development decision-making process: a holistic framework. American Journal of Economics and Sociology. 36(1):1–17.

Gardner, J.E., and J.G. Nelson. 1980. Comparing national park and related reserve policy in hinterland areas: Alaska, northern Canada and northern Australia. Environmental Conservation. 7(1):43–50.

Gillespie, D. and M. McComb. 1984. Environment Canada's northern conservation lands plan (draft). Ottawa. January.

Hall, R., J. Clark, P.C. Giordano, P.V. Johnson, M. Van Roekel. 1978. Interorganizational coordination in the delivery of human services. In: Lucien Karpick, ed. Organization and environment. Theory, issues and reality. London: Sage Publications.

Halpert, B.P. 1982. Antecedents. In: D.L. Rogers and D.A. Whetten, eds. Interorganizational coordination: theory, research and implementation. Ames, Iowa: State University Press. 54–72.

Hanf, K. 1977. Joint decision making in the German Democratic Republic: an interorganizational perspective on policy and planning. In: E.H. Burack and A.R. Negandhi, eds. Organization design: theoretical perspectives and empirical findings. Kent, Ohio: Comparative Administration Research Institute, Kent State University.

Ideli, Bennet Echeta. 1973. An interagency coordination model for rural community development. Unpubl. M.A. thesis, University of Guelph, Ontario.

Jewell, L. and J. Reitz. 1981. Group effectiveness in organizations. Glenview, Illinois: Scott Foresman and Company.

Koenig, R.J. 1981. The interorganizational network as a system: toward a conceptual framework. In: G.W. England, A.R. Neganhi and B. Wilpert, eds. The functioning of complex organizations. Cambridge, Massachussetts: Oelgeschlager, Gunn and Lain Publishers Inc. 275–302.

Molnar, J.J. and D.L. Rogers. 1982. Interorganizational coordination in environmental management: process, strategy and objective. In: L.E. Mann, ed. Environmental Policy Implementation. Toronto: Lexington Press. 95–108.

Morrissey, J.P., R.H. Hall, M.L. Lindsey. 1982. Interorganizational relations: a sourcebook of measures for mental health progress. U.S. Department of Health and Human Services. Series BN no. 2 Washington, D.C.: National Institute of Mental Health.

Mott, B.J. 1968. Anatomy of a Coordinating Council. Pittsburgh: University of Pittsburgh Press.

Mulford, C.L. and D.L. Rogers. 1982. Definitions and models. In: D.L. Rogers and D.A. Whetten, eds. Interorganizational Coordination. Ames, Iowa: Iowa State University Press. 9-31.

National Park Provisions of an Agreement-In-Principle. 1983. Rankin Inlet: Tungavik Federation of Nunavut. July 27.

Negandhi, A.R. (ed.) 1975. Interorganizational theory. Kent, Ohio: Kent State University Press.

Neufeld, D.A. 1985. Interorganizational cooperation in planning and managing national parks and national wildlife areas in the Northwest Territories. Unpubl. M.A. thesis, School of Urban and Regional Planning, University of Waterloo, Ontario.

Northwest Territories, Department of Economic Development and Tourism. 1981. Principles concerning the establishment, development and operation of new national parks in the Northwest Territories.

Reid, W. 1964. Interagency coordination in delinquency prevention and control. Social Service Review. 38(4):418-428.

Reitz, H.J. 1977. Behavior in Organizations. Homewood, Ill.: Irwin Press.

Rogers, D.L. and D.A. Whetten (eds.). 1982. Interorganizational Coordination. Ames, Iowa: Iowa State University Press.

Rogers, D.L. and M. Maas. 1977. Interagency planning for natural resource management. Sociology Report 137. Ames, Iowa: Iowa State University, Department of Sociology.

Trist, E. 1983. Referent organizations and the development of interorganizational domains. Human Relations. 36:269-284.

Tuite, M. 1972. Toward a theory of joint Decision Making. In: M. Tuite, R. Chrisholm, M. Radnor, eds. Interorganizational Decision Making. Chicago; Aldine Publishing Company. 9-19.

Van de Ven, A.H. and D.L. Ferry. 1980. Measuring and Assessing Organizations. New York: John Wiley and Sons.

Verberder, R. 1982. Working Together. Fundamental group decision making. Belmont, California: Wadsworth Publishing Company.

Walton, R. 1972. Interorganizational decision making and identity conflict. In: M. Tuite, R. Chrisholm, M. Radnor, eds. Interorganizational Decision Making and Identity Conflict. Chicago: Aldine Publishing Company. 94-111.

Walton, R.E., J.M. Dutton, T.D. Cafferty, 1969. Organizational context and interdepartmental conflict. Administrative Science Quarterly. 14:522-543.

Warren, R. 1972. The concerting of decisions as a variable in organizational interactions. In: M. Tuite, R. Chrisholm, M. Radnor, eds. Interorganizational Decision Making. Chicago: Aldine Publishng Company. 20-32.

Warren, R. 1967. The interorganizational field as a focus for investigation. Administrative Science Quarterly. 12:396-419.

Western Arctic Claim. The Inuvialuit Final Agreement. 1984. Ottawa: Indian and Northern Affairs Canada.

Whetton, D.A. and B. Bozeman. 1984. Policy coordination and interorganizational relations. Some guidelines for sharing power (draft). Prepared for the Conference on Shared Power. Hubert Humphrey Institute of Public Affairs, University of Minnesota, May 9-11.

Whetten, D.A. 1977. Toward a contingency model for designing interorganizational service delivery systems. Organization design: Theoretical perspectives and empirical findings.

Wildlife Provisions of an Agreement-In-Principle. 1981. Ottawa: Tungavik Federation of Nunavut. October 27.

HISTORICAL VARIATIONS IN COPPER AND CARIBOU INUIT SKIN CLOTHING FASHIONS

Jill Oakes

Department of Clothing and Textiles, University of Manitoba, Winnipeg, Manitoba R3T 2N2

Level: Ph.D.

Abstract

Historical and current skin clothing fashions were collected from Copper Inuit in Bay Chimo, Cambridge Bay and Coppermine and from Caribou Inuit from Eskimo Point, Rankin Inlet and Whale Cove. Field work began in October 1985 and will continue until August 1987. Archival and museum research, conducted from May — September 1985, supplemented historical information from Inuit elders. The main objective was to identify individual, regional and historical patterns in skin preparation, skin clothing construction and caribou skin fashion features. This paper focuses on historical and current fashion trends in everyday-wear and special occasion caribou skin parkas.

Regional and historical differences in fashions were influenced by physical, economic and social environments. Animal distributions, trapping, wage economy jobs, traders, whalers, tourists and interaction with neighbouring native groups influenced parka fashions. Cross-cultural diffusion of fashion features from neighbouring Inuit produced the most significant fashion innovations.

Key words: Skin clothing, Copper Inuit, Caribou Inuit, fashion, skin clothing construction, Canadian dress, historical dress.

Résumé

Cette étude porte sur les techniques de préparation des peaux de caribou et de confection des vêtements de peau dans le cadre de trois cultures traditionnelles distinctes à Eskimo Point et dans la région de Coppermine. Les recherches dans les archives, les musées et la littérature technique ont commencé en octobre 1985, et dureront jusqu'en septembre 1987. Leur principal objectif est de mettre en évidence les méthodes de préparation et de confection et les particularités vestimentaires qui varient selon les individus et au sein des groupes, et selon les régions et le moment. Les résultats étayeront peut-être la théorie rattachant les ascendants des Inuit du caribou de l'intérieur aux Inuit du cuivre plutôt qu'aux Inuit de Thulé.

C'est une méthode d'observation et de participation active qui est utilisée pour les recherches. Les peaux sont choisies, étirées, séchées et assouplies, et les vêtements de peau sont

mesurés, découpés, ajustés, cousus et entretenus selon les directives de couturières inuit de chaque localité. Le Vêtement terminé est utilisé par le chercheur pour la chasse, les danses rythmées au tambour, au cours des festivités de Noël et de Pâques, et pour les excursions hivernales. L'utilisation étendue des vêtements de peau entraîne des variations régionales de coupe et d'entretien, des avantages et des inconvénients, et diverses raisons de les utiliser dans un cadre actuel. L'analyse réalisée jusqu'ici a mis en évidence les relations entre la confection de vêtements de peau et des facteurs tels que les fluctuations de la répartition des caribous, l'intervention des non-indigènes tels que les agents de traite, les missionnaires et les baleiniers, et les interactions avec les groupes autochtones voisins.

Mots-clés: Vêtement de peau, Inuit du cuivre, Inuit du caribou, coupe vestimentaire, préparation des peaux, confection des vêtements de peau, éducation dans l'Arctique.

Introduction

Custom, in the clothing sense, refers to clothing features passed from one generation to the next while fashion refers to features which change from one generation to the next (Sproles, 1979). Usually new fashions are slightly modified old fashions although rapid changes do occur (Sproles, 1979). Inuit skin clothing contains examples of fashion and custom. The pullover and tailored aspects of Inuit parkas are customs; the hemline, shoulder, pouch, hood and decorative features are classified as fashions. Fashion and custom are products of the social, economic and physical environment in which the clothing is worn (Sproles, 1979). This paper discusses Copper and Caribou Inuit caribou skin parka fashions, as well as the historical events that stimulated fashion changes.

During 1985 and 1986, 54 Copper Inuit at Coppermine, Cambridge Bay and Bay Chimo, and 45 Caribou Inuit at Eskimo Point, Whale Cove and Rankin Inlet taught the author how to make historical and current fashions. Participant-observation in skin clothing production and usage provided details on construction processes and the function of skin clothing.

Museum and archival research supplemented historical information collected from community elders. Clothing construction, styles and functions, skin preparation and pattern development will be described in the author's dissertation at the University of Manitoba, Winnipeg.

Copper Inuit skin clothing fashions

From the mid-1800's to the early 1900's, Copper Inuit traded with Netsilik, Iglulik and Caribou Inuit; interaction with non-natives was scarce. Detailed descriptions, photographs and artifacts of Copper Inuit clothing were not collected until 1913 (Jenness, 1921; 1922; 1946).

Key fashion features in the man's hunting and dance parka between 1900–1916 included: a mid-calf length back tail, waist length front hemline, slightly longer inner parka, broad shoulders, sleeves cut about an inch above the wrist, a peaked hood and white-haired caribou skin chest panels (National Museum of Canada IV-D-1170; McCord Museum, ME967X.41). Women's parkas were similar to men's except women's parkas had extra fullness across the back and the hood was a long, lobular shape with a center seam (Stefansson, 1914) (Fig. 1). Dance parkas were often hoodless and the chest panels were decorated with minute squares and stripes of red, white and black caribou skin sewn between the chest panels (National Museum of Canada IV-D-693). Weasel skins, colored beads, caribou fringes, caribou teeth, polar bear claws and seal knuckle bones were also popular decorations. Tassels, tokens of friendship, were sewn to the parka's right shoulder (Jenness, 1922).

Figure 1. Copper Inuit Woman's Outer Parka. The hemline, shoulder silhouette, and chest decorations on women's parkas were similar to men's parkas in the early 1900's. Photo credit Prince of Wales Northern Heritage Centre Archives 73PH473.

In the early 1900's, when the whaling industry collapsed in the Western Arctic, some whaling ships were converted to floating fur trading posts and piloted eastward. Western Arctic Inuit were hired as interpreters and navigators to facilitate trade with Copper Inuit. Increased contact with Western Arctic Inuit, including extensive contact with Captain Klengenberg's Inupiat wife, introduced the Western Arctic parka to the Copper Inuit (Jenness, 1946).

By 1918 men's and women's everyday-wear and dance parka hemlines plunged; men's to the upper-thigh, women's to the mid-calf. The women's inner parka was about six inches longer than the outer parka, exposing a printed cotton covering over the inner caribou parka. The parka shoulders

became rounded, fitting the body contours. White chest panels were omitted, white side panels appeared on the hood. The men's hood style was unchanged; women's hoods were changed to the men's style and a tiny pouch was added to the center back area. Women's hoods were trimmed with wolverine and wolf; men's with wolverine or wolf. Hemlines were decorated with geometric pieces of white- and black-haired caribou skin. Strips of wolverine or wolf were used to finish the cuffs, hemlines and shoulder tassels.

Subtle fashion changes occured throughout the ensuing decades. In the 1940's, men's parka hemlines dropped down to just above the knee, curving up towards mid-thigh. A similar style was worn by Kittagazuit from the Mackenzie Delta (Public Archives of Canada PAC/CAP — C23640, C23642). Women's inner and outer parka hemlines were cut to mid-calf, with the outer parka slightly longer than the inner parka.

By the 1950's, men's parka hemline and hood fashions changed. The front hemline remained just above the knee, dropping below the knee in the back. Women's hemlines remained at the mid-calf length and became slightly longer in the back. Men wore rounded hoods with white side panels; women's were unchanged.

From the 1970's to date, public drum dances, community frolics and festivals, cultural events in the Arctic Olympics and tourism stimulated an increase in dance costume decorations. Today, the basic style is unchanged, however, the hemline, shoulder seams, front seams, shoulder blade seams and hood seams are decorated with mosaic bands of white- and dark-haired trim. Wolverine tassels, stained with red fabric dye, are sewn to the shoulders, front and back areas (Fig. 2). Slightly less decorated parkas are worn by men and women when travelling on the land during the winter and spring.

Children wore miniature versions of their respective sex's parka fashion throughout the 1900's (Royal Ontario Museum, HC2838; National Museum of Canada, IV-D-1259). In the 1950's, children wore beaded hearts as friendship tokens on their parkas.

Caribou Inuit parka fashions

From the early 1700's until 1790, the Hudson's Bay Company sent floating trading posts along the western Hudson Bay coastline and traded a variety of supplies, including beads, for caribou skins and sea-mammal blubber (Graham, 1969). After 1790, when the floating trading posts were cancelled, Caribou Inuit occasionally travelled to Fort Churchill to trade (Burch, 1986). Although skin clothing sketches and descriptions are rare for this era, beads were likely used as decorations. Ellis (1748) encountered Inuit on the northwestern shores of Hudson Bay, wearing pullover parkas with waist length fronts and calf length tails. Similar parkas were worn in 1824 and 1825 by Caribou Inuit men while trading with overwintering explorers on Winter Island. Small strands of string beads were sewn to the parka's shoulders and lower back (Lyon, 1825). Similar parkas were also used by Netsilik, Iglulik and Copper Inuit with whom Caribou Inuit frequently traded (Oakes, in preparation).

Figure 2. Copper Inuit man's parka. Sam Kikpak wears his Copper Inuit style parka enroute from Coppermine to Bay Chimo. Travelling parkas are less elaborately decorated than parkas used strictly for drum dances. Photo credit J. Oakes.

From 1860 to 1904, trade with overwintering American whalers in the northwestern Hudson Bay area provided Caribou Inuit with a continuous supply of beads (Birket-Smith, 1929; Low, 1906). Beads became a distinguishing feature of their parkas. When beads were unavailable, women used animal teeth, bones and ivory (Tyrrell, 1897).

By the 1920's, the Caribou Inuit man's hunting parka hemline had dropped to a straight line, about six inches above the knee. Occasionally the back hemline was slightly longer than the front. White-haired caribou insets commonly decorated northern Keewatin communities; southern communities rarely used white-haired caribou skin on men's parkas. Caribou skin was used around the hemline and hood opening, unlike the use of wolverine or wolf by Copper Inuit. The dress coat was an elaborately decorated version of the 1800's hunting parka style. It had a long back tail, waist length front hem and two beaded duffel chest panels. A panel of beadwork was sewn across the back and a cluster of string beads was sewn to the hood peak (Royal Ontario Museum, HC2297; National Museum of Canada, IV-C-2664).

Since the early 1900's, Inland Caribou Inuit (Ahiarmiut) women have preferred an elongated hood with a center back seam similar to the early Copper Inuit fashion. Coastal Caribou Inuit (Paallirmiut) women's hoods are elongated, however, the seam encircles the hood like Aivilingmiut hood seams from Southampton Island. The long back tails, short narrow front tails and broad shoulders are distinguishing fashion features with style variations unique to each group (Oakes, in preparation). The inner parka is decorated with beadwork; string bead fringes were finished with caribou teeth, beaded loops or lead weights (National Museum of Canada, IV-C-663; IV-C-709; Royal Ontario Museum, HC2357). Trim and fringes on women's parkas have changed since trading posts were established.

In the early 1920's, the Hudson's Bay Company and independent trading company posts opened in the Eskimo Point area and provided Inuit with supplies including sewing materials (Birket-Smith, 1929). Fashionable seamstresses sewed bias tape, rickrack, grosgrain ribbon, trim tape and fabrics around the hem, cuffs and hood of men's and women's inner parkas. Inland Caribou Inuit also sewed fabric around women's outer parka hems.

By the 1950's, mens' hunting parkas were knee length with side splits and slightly longer back tails. Occasionally, a band of beadwork encircled the face of the inner parka. Two chest panels made from either duffel or stroud material and edged with beadwork were sewn to the front of the man's inner hunting parka for special occasions. The dress parka faded out of style and inner parkas were worn to drum dances.

The 1960's to 1980's male and female parka silhouettes are identical to the 1950's fashion. However, decorative features and the function of caribou skin clothing changed over the last decades. Several men in Eskimo Point wear parkas with three white insets across the back, a simplified version of northern Caribou Inuit, Iglulik and Netsilik fashion (Boas, 1901). Today, beadwork on men's inner hunting parkas is unfashionable. Men reserve caribou skin clothing for hunting trips and wear fabric clothing to drum dances. On the rare occasion that women attend winter hunting trips, they wear men's hunting parkas. At drum dances women wear beaded caribou skin or fabric inner parkas (Fig. 3); caribou skin outer parkas are seldom made or worn.

Children wore two parka styles: a miniature version of the respective adult's parka, and a parka with a short, narrow tab at the centerfront hemline and a slightly longer, broader back tab. Today, the latter style is rarely made by Caribou Inuit seamstresses. Like Copper Inuit children, during the 1950's it was fashionable to wear small beaded panels exchanged between friends. Today, children from some communities give a bead to each of their friends, the bead is slipped onto a safety pin containing more beads from other friends and is pinned to fabric parkas.

Discussion

Fashion evolved primarily through cross-cultural diffusion. Since the 1700's, fashion innovators shifted between neighbouring Inuit groups and non-natives. Copper and Caribou Inuit hemlines, hoods, pouches and decorative chest panels were similar to each other and other Central-Eastern Arctic Inuit until the early 1900's. The introduction of floating trading posts, owned by non-natives who hired native interpreters, exposed Copper Inuit to Mackenzie Delta Inuit and Inupiat fashions. Non-native traders encouraged contact between Central-Eastern Arctic and Caribou Inuit earlier in history, influencing the exchange of fashion features.

From the 1940's to 1980's, interaction with non-natives gradually increased. Mass produced parkas and fabric for homemade parkas was available from trading posts. Inuit often made cloth, pullover parkas with a rounded hood, similar to the ready-made parka hood styles. Rounded hoods also became popular in skin parka fashions, a feature which may be attributed to non-native fashion innovators. New sewing supplies also influenced Copper and Caribou Inuit parka hems.

Figure 3. Caribou Inuit woman's parka. Annie Sewoee, Eskimo Point, wears a beaded parka similar to the styles worn in the early 1900's. Photo credit J. Oakes.

Economic and physical influences, created by the presence of non-natives, stimulated parka fashions. Economic influences including the introduction of trapping, municipal jobs and government social services introduced new fashion innovations. Successful trappers and wage earners were able to acquire more supplies, including fabric and beads. Copper Inuit demonstrated their wealth by making the inner cotton liner longer than the outer. Less successful trappers were unable to make such long inner parkas. Caribou Inuit used beadwork and purchased trims as prestigious decorations. Beadwork from old garments was combined with new beadwork, bias tape and grosgrain ribbon. In the 1950's and 1960's, government social services made it possible for unemployed Inuit to obtain luxuries such as beads, fabric and trim. Copper Inuit women's inner parka hemlines were cut shorter than the outer parka.

The physical environment contributed to fashion choices by limiting the types of available animal skins, restricting fashion extremes, and increasing drum dancers' public exposure. Wolverine skins are readily available to Copper Inuit and are used extensively for clothing trim. Caribou Inuit use caribou skin fringes; wolverine is scarce in the southern Keewatin.

The tailored, pullover custom of skin clothing provides protection from the harsh climate. Fashion features are more variable and often less practical, however, extremes are limited by the climate. The 1700's and 1800's Copper and Caribou Inuit parkas were as short as feasible. If the front hemline was any shorter it would provide inadequate protection from the cold. As it was, the inner parka was cut slightly longer than the outer parka and chest high caribou skin underwear was worn underneath the parkas to keep the body torso warm (Jenness, 1946).

During the 1970's and 1980's, special occasions began to change from private celebrations held in personal homes and enjoyed by small groups to public displays viewed by large numbers of strangers. Drum dances are now held at Arctic Olympics, community festivals, Expo '86, summer demonstrations for tourists, Inuit Broadcasting Corporation and Canadian Broadcasting Corporation programs as well as in private homes and local community halls. Drum dancers receive increased public exposure and are performing in large, centrally heated buildings which has stimulated changes in decorative features and materials used in dance parkas. Dance parka fashions generally followed the same fashion trends as everyday-wear until the 1930's and 1940's. Then the old fashions were retained and decorated for special occasions while new hunting fashions evolved. As drum dances began to receive more exposure, dance costumes were more elaborately decorated and fabrics were often substituted for caribou skin. Copper Inuit male and female dance parkas evolved into highly decorated outer parkas worn without inner parkas. Today, Caribou Inuit women continue to wear elaborately beaded inner parkas. Men wear fabric versions of their hunting parkas at large public gatherings, regular work clothes are worn at local community events.

Conclusion

Inuit parkas are excellent examples of classical fashion concepts such as custom in dress, the gradual evolution of fashion and sudden fashion changes occurring when styles reach their most extreme positions. Generally, Inuit fashions evolved slowly, making small changes in one fashion feature and leaving other features unchanged. A classic illustration of the total acceptance of revolutionary styles occurred when Copper Inuit parka front hemlines were as short as feasible and within two years mid-calf length parkas were commonplace.

Cross-cultural diffusion of fashion occurs primarily between neighbouring Inuit groups. Non-natives' influence was limited mainly to the introduction of new materials which Inuit incorporated into their skin clothing styles. Indians had no recognizable influence on Inuit skin fashions, however, additional research is required to determine Indian influences on Inuit fabric fashions. Other social, economic and physical influences include tourists, municipal jobs, trapping, animal distributions and changing lifestyles.

Additional research is required to determine current fashion innovators; factors which restrict fashion acceptance; and social, economic and physical environment factors stimulating fabric fashions in arctic communities.

Acknowledgments

The seamstresses and interpreters from Bay Chimo, Cambridge Bay, Coppermine, Eskimo Point, Rankin Inlet and Whale Cove are gratefully acknowledged for their cooperation and support throughout this research project. Their awareness of historical and current clothing styles made this research possible. The staff at the Glenbow Museum, McCord Museum, National Museum of Canada, Prince of Wales Northern Heritage Center, Royal Ontario Museum, National Archives, Hudson's Bay Archives, Manitoba Provincial Archives, and Prince of Wales Northern Heritage Center Archives, are thanked for their cooperation. Support from the Manitoba Department of Natural Resources, GNWT Renewable Resources, Calm Air, Northwest Territorial Airways, Keewatin Air, University of Manitoba Graduate Fellowship Fund and Northern Scientific Training Grant, University of Manitoba is sincerely appreciated.

References

Birket-Smith, K. 1929. The Caribou Eskimos; Material and Social Life and Their Cultural Position. Report of the Fifth Thule Expedition, 1921-24. Vol 5(1-2). Copenhagen.

Burch, E. 1986. The Caribou Inuit. In The Native Peoples: The Canadian Experience. B. Morrison and R. Wilson (editors). Toronto: McClelland and Stewart Ltd.

Boas, F. 1901-1907. The Eskimo of Baffin Land and Hudson Bay. Bulletin of the American Museum of Natural History Vol XV (I). New York.

Ellis, H. 1748. A Voyage to Hudson's Bay by the Dobbs Galley and California in the Years 1746 and 1747, for Discovering a North West Passage; with an Accurate Survey of the Coast, and a Short Natural History of the Country. Together with a Fair View of the Facts and Arguments from Which the Future Finding of Such a Passage is Rendered Probable. London: H. Whitridge. (Reprinted: S.R. Publishers, East Ardsley, U.K., 1967.)

Glenbow Museum. Artifact number AB 733a. Edmonton, Alberta.

Graham, A. 1969. Andrew Graham's observations on Hudson's Bay 1767-91. Glyndwr Williams, ed. Publications of the Hudson's Bay Record Society 27. London.

Jenness, D. 1921. The cultural transformation of the Copper Eskimos. Geographical Review 11(4):540-551.

_____. 1922. The Life of the Copper Eskimos. Report of the Canadian Arctic Expedition 1913-1918 Vol 12(a). Kings Printer: Ottawa.

_____ 1946. Material Culture of the Copper Eskimo. Report of the Canadian Arctic Expedition 1913-1918 Vol 16 Southern Part 1913-1916. Kings Printer: Ottawa.

Low, A. 1906. Report on the Dominion Government Expedition to Hudson Bay and the Arctic Islands on Board the D.G.S. Neptune, 1903-1904. Ottawa: Government Printing Bureau.

Lyon, G. 1825. A Brief Narrative of an Unsuccessful Attempt to Reach Repulse Bay, Through Sir Thomas Rowe's "Welcome," in His Majesty's Ship Griper, in the Year MDCCCXXIV. London: J. Murray.

National Museum of Canada. Artifact numbers IV-C-663, IV-C-709, IV-C-2664, IV-D-693, IV-D-1170, IV-D-1259.

Oakes, J. Variations in Copper and Caribou Inuit Skin Clothing Production. Interdisciplinary Ph.D. dissertation. University of Manitoba, Winnipeg. In preparation.

Public Archives of Canada. PAC/CAP-C23640, PAC/CAP-C23642, PAC/CAP-C19690, PAC/CAP-C19691. Ottawa.

Royal Ontario Museum. Artifact number HC2297, HC2357, HC2838. Toronto.

Sproles, 1979. Fashion: Consumer Behavior Toward Dress. Burgess Publishing Company: Minneapolis.

Stefansson, V. 1914. The Stefansson-Anderson Arctic Expedition of the American Museum: preliminary Ethnological Report. Anthropological papers of the American Museum of Natural History Vol XIV(I). New York.

Tyrrell, J.W. 1897. Across the Sub-arctic of Canada: A Journey of 3,200 Miles by Canoe and Snowshoe Through the Barren Lands. Toronto: W. Briggs.

PATTERN DEVELOPMENT IN ESKIMO POINT, N.W.T.

Jill Oakes

Department of Clothing and Textiles, University of Manitoba, Winnipeg, Manitoba R3T 2N2

Level: Ph.D.

Abstract

Traditional clothing patterns from the Paallirmiut, Ahiarmiut and Tahiujarmiut in the Eskimo Point area were collected from December 1985 to September 1986. The main objective was to preserve traditional clothing styles for future generations to use. The collection of patterns are included in a proposed skin clothing exhibition designed to increase museum awareness in northern Canada.

Seamstresses taught the author pattern development methods using hand, eye and string measurements. Pattern lay-outs were recorded for all garments. Patterns were catalogued, accessioned, duplicated and stored at the Inuit Cultural Institute, primarily for use by northern seamstresses, educators and museums. A complete description of pattern development for all garments will be included in the author's dissertation. Male and female caribou skin parka patterns are described and discussed in this research summary. Paallirmiut, Ahiarmiut and Tahiujarmiut parka patterns non-verbally communicate group identity, conformity, and social affiliation with neighbouring groups.

Key words: Eskimo Point, Caribou Inuit, pattern development, hand measurements, heritage, skin clothing, history, Inuit museums, dress norms, group identity.

Résumé

L'auteure a rassemblé les vêtements traditionnels des Paallirmiuts, Ahiarmiuts et Tahiujarmiuts de la région d'Eskimo Point de décembre 1985 à septembre 1986. L'objectif principal était de préserver les vêtements traditionnels pour y intéresser les générations futures. On expose actuellement cette collection de vêtements de peau en vue de sensibiliser la population nord-canadienne à l'utilisation des musées.

Les couturières qui savaient comment confectionner les vêtements traditionnels n'avaient pas d'expérience du tracé des patrons en papier. Elles prenaient des mesures avec leurs mains ou une ficelle, ou évaluaient visuellement les pièces à découper dans les peaux de caribou. On découpa des doubles en peau des patrons en papier, afin de s'assurer de l'exactitude de ces derniers. De nombreuses pièces furent découpées directement dans la peau de caribou et reproduites sur papier avant d'être cousues. Pour tous les vêtements, on nota les détails du choix des peaux et du tracé des patrons. On établit la liste des patrons, qu'on répertoria, reproduisit et emmagasina à l'Institut culturel inuit, dans le but premier de servir aux couturières autochtones, aux enseignants et aux musées. L'auteure achèvera son analyse de la collection, et la décrira dans sa dissertation.

Mots-clés: Eskimo Point, Inuit du Caribou, tracé des patrons, mesure manuelle, patrimoine culturel, vêtements de peau, musée inuit.

Introduction

Small communities acquire fashion ideas primarily through social interaction within the community and with neighbouring communities. Accepting a group's dress style is an important key to social acceptance, demonstrating a willingness to conform and cooperate with the new group (Sproles, 1979). Total acceptance of another group's style symbolizes group membership (Horn, 1975). Inuit women create tailored clothing that provides excellent protection, symbolizes community identity, and non-verbally communicates social ties with neighbouring groups. Pattern development procedures are passed down from one generation to the next using hand, string, and eye measurements (Angugatiaq, 1973; Hatt, 1914; Manning & Manning, 1944; Mathiassen, 1928; Oakes, 1985; Pharand, 1975; Turner, 1889). Actual descriptions of how to make patterns using the above mentioned measuring techniques are rare (Oakes, 1985), yet elders strongly urge women to return to making caribou skin clothing for winter use (Elders' Conference, 1984). This research describes local pattern development methods and compares patterns on an individual, subgroup and group level. Eskimo Point is comprised primarily of Ahiarmiut (Inland Inuit), Paallirmiut (Coastal Inuit). A small group of people who travel between the two groups, spending several years in each area, are called Tahiujarmiut (Steenhoven, 1955). Measuring techniques were collected from 1985 to 1986 in Eskimo Point, Northwest Territories through active participant-observation. Ahiarmiut, Paallirmiut and Tahiujarmiut (Fig. 1) taught the author measuring techniques, pattern lay-outs, cutting procedures, seam construction and alteration techniques. Patterns were copied from caribou skins to paper. Pattern layout, construction instructions, and name, age, cultural group or subgroup of the original designer were recorded on each pattern piece. The author donated the patterns to the Inuit Cultural Institute after they were analyzed. The author, in conjunction with the Inuit Cultural Institute and Prince of Wales Northern Heritage Center, intends to display some of the patterns in an Inuit clothing exposition.

All types of garments were studied, however, this paper limits the discussion to men's and women's inner and outer parkas. A detailed discussion is included in the author's dissertation which will be presented to the University of Manitoba, Winnipeg.

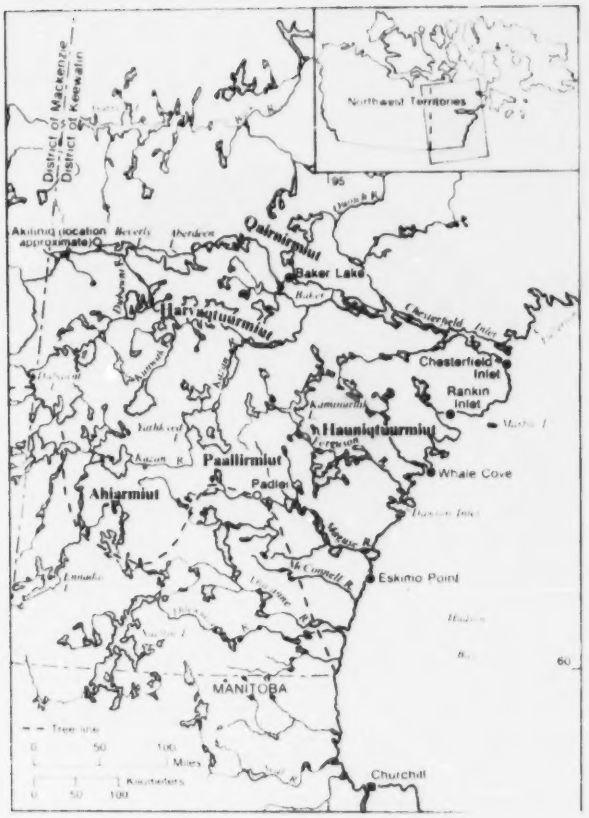


Figure 1. Map of the Eskimo Point Area (Arima, 1984). Eskimo Point is inhabited primarily by Ahiarmiut and Paallirmiut.

Pattern development

The following pattern development instructions create medium sized patterns (Men's size 38–42, Misses' size 32–36) using medium sized seamstress' hands (Woman's size 6 1/2 — 7 1/2). Larger and smaller sizes are fitted by altering the length and width of side, sleeve, shoulder and hood seams.

Man's inner parka pattern

The complexity of pattern development is obvious to the beginner, experienced seamstresses cut out an inner parka in less than an hour. Their speed and confidence make the task appear simple. The man's inner parka consists of a back (Fig. 2A), front (Fig. 2B), sleeve and side-hood pattern. The first measurement on a Paallirmiut man's back pattern is made by measuring half a hand span from the tip of the hood (a) to the hood's crown (b) (Fig. 2A). The length (b-c) and width (d-e) of the hood measures two hand spans. The shoulder seam (f-g) equals one and a half hand spans long and the side seams (h-i) are two hand spans long. The neck hole on the front pattern is one hand span long (m-n) and one hand span wide (n-o) (Fig. 2B). The front armhole (u-v) is one palm width wide and one and a half hand spans from the shoulder seam (r-v). The front shoulder and side seams are cut to match the back pattern.

Unlike Paallirmiut patterns, Ahiarmiut have a high broad peak, a flat crown, and a loosely fitted face line on the hood. The back hem line is slightly less than a hand span longer than the front and is rounded up to the side split. Paallirmiut and Tahiujarmiut patterns have a small narrow peak, a full gathered crown, and a closely fitted face line on the hood. The back hem line is about two-knuckles longer than the front and broadly curves up to the side split.

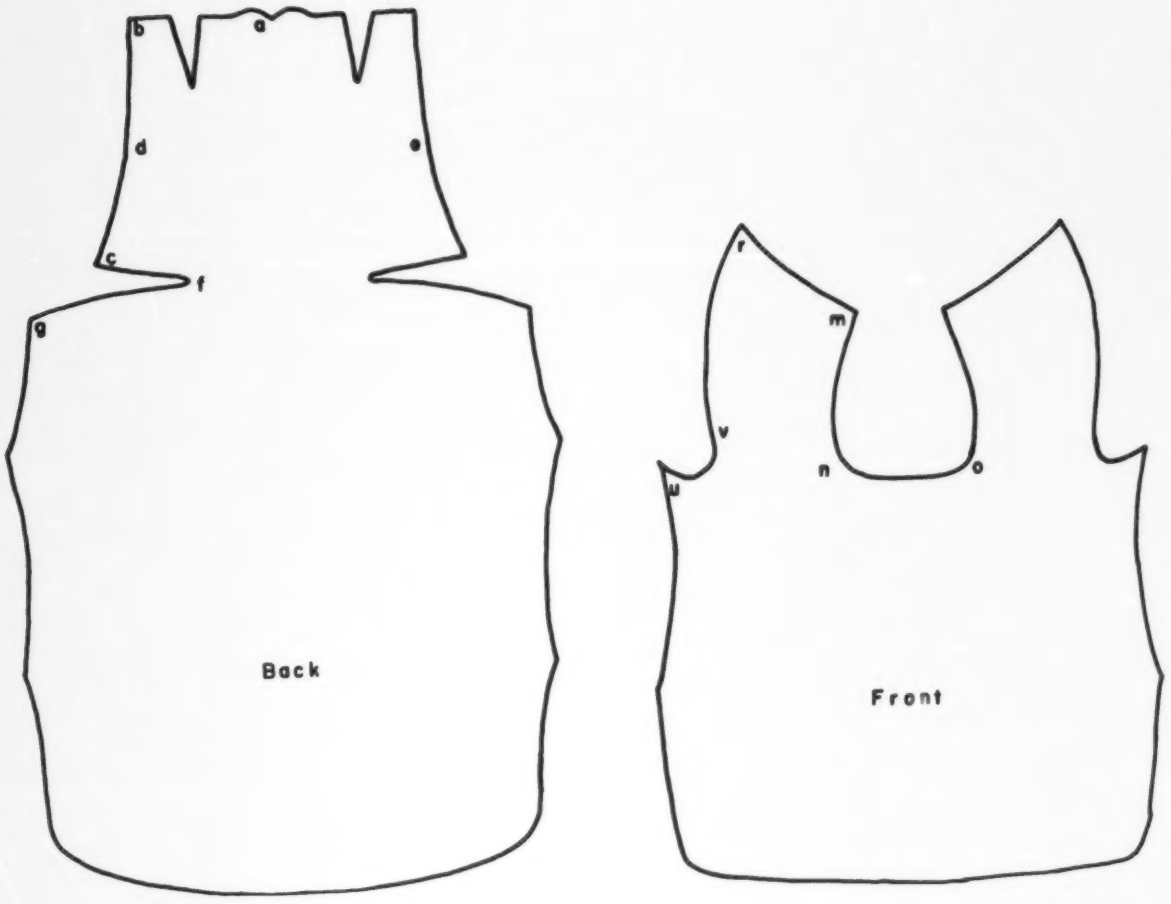
The outer and inner Caribou Inuit parka patterns are identical: the outer parka is worn with the hair to the outside and the inner parka is worn with the hair towards the body. Differences in decoration and pattern layout occur between the Ahiarmiut and Paallirmiut seamstresses. Paallirmiut seamstresses create two white armbands on the outer parka by cutting the cap and center sleeve section from the tail edge of two skins. Similar sleeve lay-outs are used by the Iglulingmiut of Iglulik (Igloolik Adult Education Center, 1985; Mathiassen, 1928). Ahiarmiut cut the cap and center section from one piece, with the caribou tail area placed next to the wrist section. Paallirmiut cut the wrist section from the caribou neck area with the hair grain running downwards, Ahiarmiut prefer the hair grain to run around the wrist.

A third parka style is used by several men in Eskimo Point. This parka has three white-haired caribou skin insets sewn across the back. Several women sew this style, although only one woman (a Paallirmiut) cuts out the pattern pieces. Similar patterns from Baker Lake, Chesterfield Inlet and Iglulik divide the white blocks in half with pieces of dark-haired caribou skin (Mathiassen, 1928; National Museum of Canada, IV-C-4080; IV-C-582; IV-C-578; Pharand, 1975).

Woman's inner parka

A woman's inner parka pattern consists of front, back, sleeve, side-pouch and hood pattern pieces. Patterns are measured directly onto the caribou skin, by eye, using the caribou hair as a guideline. An advanced understanding of the physical properties of each caribou skin is required to make the best cut. For example, the parka's broad shoulder pattern is positioned over the top of the caribou's leg area. The change in hair direction from the caribou's center back area to it's leg area conveniently covers the armscye seam. The scantly haired axilla (caribou armpit) area is cut away, creating the garment's indented armhole. Side seams are cut approximately one and a half hand spans from the fold line and are about one hand span long. The curving hemline is drawn by running a finger through the richly colored, thick, center back caribou hair. The skin is pinched or bitten to mark the cutting line.

Paallirmiut seamstresses cut the shoulders about three inches broader than Ahiarmiut and about one inch broader than Tahiujarmiut shoulders. Paallirmiut and Tahiujarmiut cut the front tail about one hand span longer and half a hand span wider than the Ahiarmiut; the back tail is about one hand span shorter and half a hand span narrower than Ahiarmiut patterns. Subtle differences between Ahiarmiut and Paallirmiut neck lines are significant to seamstresses experienced at sewing similar styles. The Ahiarmiut neckline (a-b) is continuous and the Paallirmiut neck line (w-x-y) contains an extension (x) at the center back



2a Back 2b Front

Figure 2. Paallirmiut Man's Inner Parka Back and Front Pattern. The tip of the hood (a) to the crown (b) is half a hand span. The length (b–c) and width (d–e) of the hood is two hand spans. The shoulder seam (f–g) is one and a half hand spans and the side seams (h–i) are two hand spans long. The neck hole (m–n, n–o) is one hand span long, the front armhole (u–v) is one palm width wide and one and a half hand spans from the shoulder seam (r–v).

(Fig. 3AB). Also, Ahiarmiut pouch slash lines (c–d) angle away from the center back fold line while Paallirmiut slash lines (u–v) are cut almost parallel to the center back fold.

The elongated hood is a key identifying feature used by Caribou Inuit (Birket-Smith, 1929). Slight variations are seen in Eskimo Point. The Ahiarmiut hood pattern consists of a right and left pattern piece. Pieces are placed on the bottom half of a caribou skin with the face edge closest to the skin's center back.

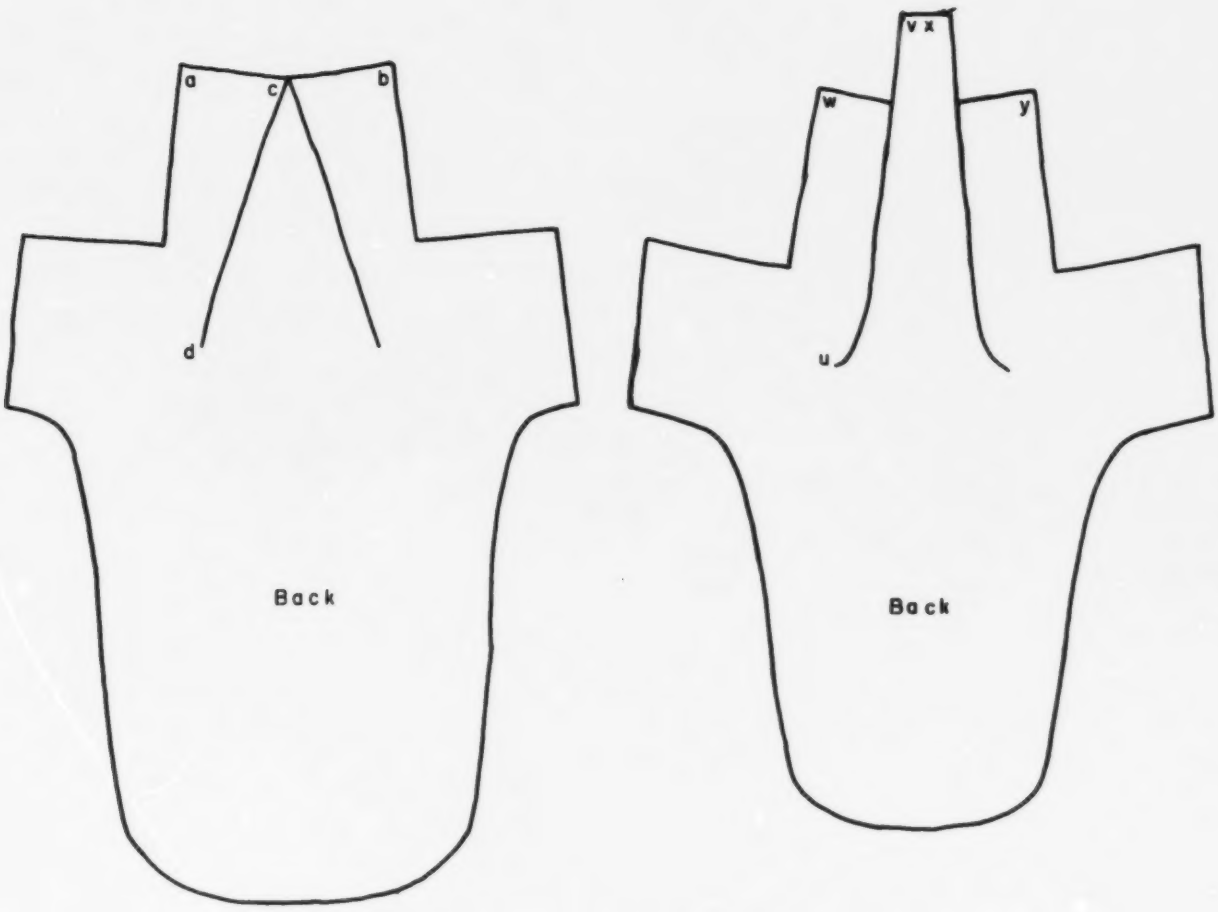
Tahiujarmiut seamstresses use a pattern and lay-out similar to the Ahiarmiut except the Tahiujarmiut hood is wider, necessitating a large oval inset at center back.

Paallirmiut hood patterns consist of a side panel and a back piece. The side-hood panel is placed at the lower edge of a caribou skin, with the pattern's face edge placed on the outer edge of the skin.

Woman's outer parka

The outer parka patterns are cut out in the same manner as the inner patterns. The hemline, sleeves, pouch and hood are trimmed with white-haired caribou skin. Paallirmiut and Ahiarmiut sew a broad band of white-haired caribou skin around the hemline. Occasionally a narrow piece of dark-haired skin is sewn in the center of the white band. In addition, Ahiarmiut sew a strip of black fabric around the face, cuffs and hem line of the outer parka (Public Archives of Canada, PA114-727).

Ahiarmiut and Tahiujarmiut parka sleeves are decorated with vertical strips of white- and dark-haired skin. Paallirmiut sleeves have horizontal white bands similar to parkas made in northern Baffin Island, Baker Lake and Chesterfield Inlet (d'Argencourt, 1981; Low, 1906; National Museum of Canada, IV-C-628)).



3A Paallirmiut 3B Ahiarmiut

Figure 3. Paallirmiut and Ahiarmiut Female Parka Back Patterns. Variations in neck lines (w–x–y; a–b) and pouch slash lines (u–v; c–d) in Paallirmiut (A) and Ahiarmiut (B) patterns create subtle identifying features.

The side panels of women's parka pouches are also cut from white-haired caribou skin. Tahiujarmiut accentuate the white panel with a dark-haired, split 't' inset; Paallirmiut by an inverted 'v'; and Ahiarmiut use white side panels without additional insets.

Discussion

From a broad perspective, Eskimo Point patterns are similar to patterns made by Caribou Inuit in other communities. The elongated hood, short front tail, longer back tail, broad shoulders, tailored pouch, and white-haired trim portray a Caribou Inuit image. A closer analysis reveals three Inuit groups represented by patterns used in Eskimo Point. Slight variations in parka hoods, sleeves and hemlines separate Ahiarmiut from Paallirmiut. Tahiujarmiut styles generally duplicate Paallirmiut styles, modifications are made to the shoulder and pouch area. Individual style modifications apart from different sizes and individual beadwork designs, are rare. Recently, one seamstress added three white-haired insets across the back of her husband's parka, imitating one aspect of caribou skin clothing styles worn by Inuit living in the northern part of the Keewatin District.

Clothing features from socially related neighbouring groups are used in local patterns. Paallirmiut patterns are similar to northern Caribou Inuit and Iglulingmiut patterns. Ahiarmiut patterns are similar to Copper Inuit and Paallirmiut. Theories of historical relationships between Ahiarmiut and Copper Inuit (Burch 1978) may be supported by similarities found in skin clothing patterns.

Fashion leaders were the elder seamstresses who taught pattern development to young women. New innovations were carried from one generation to the next. In the early and mid-1900's, populations were relatively low; about 56 Ahiarmiut in 1955 (van den Steenhoven, 1955) and 100–300 Paallirmiut in 1938 (Gabus, 1944). Today, there are about 1200 Caribou Inuit in Eskimo Point. Ahiarmiut, Paallirmiut, and Tahiujarmiut styles may have originated from one or two closely related elders.

Conclusions

Using elder's pattern development procedures is one way that young women demonstrate their willingness to become cooperating members of their cultural group. An acceptance

of local patterns communicates conformity to and acceptance of group values and norms in relation to customary dress, dress codes and fashions. Patterns also illustrate affiliations with socially related neighbouring groups.

Today, many women use skin clothing pattern styles to construct fabric parkas. Additional research is required to determine influences from neighbouring groups and non-natives in current pattern choices.

Acknowledgments

Seamstresses in Eskimo Point are gratefully acknowledged for their cooperation and patience throughout this research; their support made the study possible. Sally Karetak, Inuit Silattuqsarvingat-Inuit Cultural Institute, is acknowledged for her support and assistance with accessioning and cataloguing patterns donated to the Inuit Cultural Institute. Calm Air, Keewatin Air, Northwest Territorial Airlines, Manitoba Department of Natural Resources and Government of the Northwest Territories Department of Renewable Resources are thanked for their generous contributions. Funding from a University of Manitoba Graduate Student Fellowship and Northern Scientific Training Grant is sincerely appreciated.

References

Angugatiaq, M. 1973. Caribou garments. Inummarit 2(1):6.

d'Argencourt, L. 1981. Caribou skin preparation. Inuit Today 9:38–40.

Arima, E. 1984. Caribou Eskimo. In Handbook of North American Indians, W. Sturtevant (general editor). Vol. 5:447–462 Arctic, D. Damas (vol. editor). Washington: Smithsonian Institute.

Birket-Smith, K. 1929. The Caribou Eskimos: Material and Social Life and Their Cultural Position. Report of the Fifth Thule Expedition 1921–24 5(1–2). Copenhagen.

Burch, E. 1978. Caribou Eskimo origins: an old problem reconsidered. Arctic Anthropology 15(1):1–35.

Elders Conference. 1984. Kangiqtiniq. Rankin Inlet, 25–28 April 1983. Eskimo Point, N.W.T.: Inuit Cultural Institute.

Gabus, J. 1944a. Iglous: Vie des Esquimaux — Caribous, Mission ethnographique suisse à la Baie d'Hudson, 1938–1939. Neuchatel, Switzerland:Editions Victor Attinger.

Gabus, J. 1944b. Vie et coutumes des Esquimaux Caribous. Paris:Payot.

Hatt, G. 1914. Arktiske Skinddragter i Eurasien og Amerika: An Etnografisk Studie. Copenhagen: J.H. Schultz. (Translation Arctic Anthropology 5(2):3–132, 1969).

Horn, M. 1975. The Second Skin. 2nd Edition. Boston: Houghton Mifflin Co.

Igloolik Adult Education Center. 1985. Dictionary of Old Terms. Eskimo Point, N.W.T.: Inuit Cultural Institute.

Low, A. 1906. Report on the Dominion Government Expedition to Hudson Bay and the Arctic Islands on Board the D.G.S. Neptune, 1903–1904. Ottawa: Government Printing Bureau.

Manning, T. and Manning, E. 1944. The preparation of skins and clothing in the Eastern Canadian Arctic. The Polar Record 4(28):156–169.

Mathiassen, T. 1928. Material Culture of the Iglulik Eskimos. Report of the Fifth Thule Expedition, 1921–24 6(1). Copenhagen.

National Museum of Canada. IV-C-582, IV-C-578, IV-C-628, IV-C-4080. Ottawa

Oakes, J. 1985. Factors Influencing Skin Boot Production in Arctic Bay, N.W.T. Master of Science thesis, University of Manitoba. In Press, National Museum of Man, Mercury Series.

Pharand, S. 1975. Le Vêtement des Inuit Iglulik. Unpublished Master of Social Sciences thesis, Laval University, Quebec

Public Archives of Canada (PAC/CAP). PA114–727. Ottawa.

Steenhoven, G. van den. 1955. Study of Legal Concepts Among the Eskimos in some parts of the Keewatin District, N.W.T. in the summer of 1955. Report to the Department of Northern Affairs and National Resources, Ottawa.

Sproles, G. 1979. Fashion: Consumer Behavior Toward Dress. Minneapolis, Minnesota: Burgess Publishing Co.

Turner, L. 1894. Ethnology of the Ungava District, Hudson Bay Territory. John Murdock, ed. Pp. 159–350 in 11th Annual Report of the Bureau of American Ethnology for the Years 1889–1890. Washington.

THE PORDEN POINT THULE PROJECT: CURRENT PROBLEMS IN THULE CULTURE RESEARCH

Robert W. Park

Department of Anthropology, University of Alberta, Edmonton, Alberta T6G 2H4

Level: Ph.D.

Abstract

The Thule Culture, the direct genetic and cultural ancestor of the historic Inuit, entered the Canadian Arctic from the west approximately one thousand years ago, and survived until at least the sixteenth century in the High Arctic Islands while developing into the various historic Inuit groups on the mainland and the Low Arctic Islands. During the summers of 1984 and 1985, excavations were carried out at a medium-sized Thule site at Porden Point on the Grinnell Peninsula of Devon Island to investigate several aspects of Thule Culture subsistence and settlement in the High Arctic. In particular, an attempt was made to explore the annual round of the Thule, or at least the coastal portion of it, a goal not previously possible given the fact that only Thule winter sites have received substantial archaeological investigation.

This paper will outline some of what is known about the subsistence and settlement patterns of the Thule, and also outline some of the gaps in our knowledge. It will draw heavily on the excavation data from the Porden Point site.

Key words: Thule Culture, High Arctic Islands, Devon Island.

Résumé

Les Inuit de Thulé, ancêtres directs des Inuit modernes, à qui ils ont transmis leur culture, pénétrèrent dans l'Arctique canadien par l'Ouest il y a environ mille ans, et se maintinrent au moins jusqu'au XVI[e] siècle dans l'archipel arctique septentrional tout en se répartissant en divers groupes d'Inuit modernes sur la terre ferme et dans les îles méridionales de l'archipel. Au cours des étés 1984 et 1985, l'auteur a effectué des fouilles dans un site archéologique de superfie moyenne à la pointe Porden de la péninsule Grinnell à l'île Devon, afin de clarifier certains aspects de l'implantation et du maintien de la culture de Thulé dans l'archipel arctique septentrional. En particulier, l'auteur s'est efforcé d'éclaircir la migration annuelle des Inuit de Thulé, ou tout au moins sa partie côtière; cet objectif n'avait pu être atteint précédemment, car la fouille archéologique avait porté presque exclusivement sur les sites d'hivernement.

L'étude présente les grands traits de ce qu'on sait sur l'implantation et le maintien de la culture de Thulé, et met en relief les lacunes de nos connaissances. Elle s'étaye largement sur les données recueillies lors des fouilles au site de la pointe Porden.

Mots-clés: Culture de Thulé, archipel arctique septentrional, île Devon.

Introduction

During the summers of 1984 and 1985, archaeological excavations were carried out at a Thule Culture site in the Canadian Arctic to provide data for the author's doctoral thesis. As the analysis of the data that was recovered is not yet complete, this paper will necessarily deal more with the research problems that prompted the research rather than with conclusions, but will also attempt to outline the approaches that are being used. The research had a number of goals, but most importantly it was intended to significantly enhance our understanding of Thule Culture settlement and subsistence in the Central and High Arctic. A primary aim was to explore the annual round of the Thule, or at least that part of it which was spent on the coast. A closely related aim was to develop an understanding of the demographic and socio-economic nature of the occupations represented by different kinds of Thule sites.

The Thule Culture

It is widely agreed that the Thule Culture originated in northwestern Alaska and spread to the Canadian Arctic and Greenland during the tenth or eleventh centuries, where it lasted for several hundred years before developing into the various historic Inuit groups. One type of Thule site, generally consisting of from two to twenty or thirty semi-subterranean rock, sod and whalebone structures occupied during some or all of the winter, represents the most visible type of archaeological site in the Canadian Arctic. However, by historic times this type of winter dwelling went out of use over much of this part of the Arctic, as the Thule pattern of spending some or all of the winter at these coastal sites was replaced by the historic Inuit pattern of wintering in temporary snow house villages out on the sea ice.

Archaeological investigations of the Thule Culture have to date centered almost exclusively on the excavation of these "winter" sites. Large numbers of artifacts can usually be expected from the often permanently-frozen semi-subterranean structures found at them. Researchers have concentrated on finding out when the Thule arrived in the Canadian Arctic and the route that they took, as well as something about their later development. Given these predominantly culture-historical goals, the excavation of winter houses made good sense, since one could then compare artifact styles from different sites to make statements about the ages of the sites and their degree of inter-relatedness. Many of these archaeologists also tested or excavated a few Thule structures of other types, thought to have been occupied during warmer parts of the year, but the small numbers of artifacts found in them meant that time spent on winter houses was far more productive. Therefore, Thule activities from the seasons when they weren't occupying the winter sites have until very recently been reconstructed based on analogy with modern Inuit practices, when reconstructed at all.

Another result of the culture-historical orientation of this research has been that the actual nature of the occupation of the winter sites themselves has been given little attention. Relatively few studies have been done on the faunal bones recovered from these types of sites, and on types of subsistence activities carried out in them (e.g., McCullough, 1986). For that matter, it is not known whether all of the sites referred to as "winter" sites represent the same kind of occupation. The individual structures at these sites exhibit a large degree of morphological and structural diversity, presumably either stylistic or functional, and the number of houses at a site varies enormously. Reconstructions of the nature of site use have varied, ranging from all of the houses at winter sites having been occupied contemporaneously (e.g., McCartney 1980:525–526) to only a few of the houses at a given site having been occupied during any one winter (e.g., McGhee 1984:77–78). This problem in our understanding of Thule settlement pattern is compounded by the fact that the standard view of the Thule changing from wintering in "winter houses" to wintering in snow houses (with all the concomitant changes in subsistence practices) more or less quickly and completely may not be true. Rather, both may have been in use in a "mixed" settlement pattern for a considerable period in some parts of the Arctic, based on historic accounts (Park 1986).

However, no real approaches have been developed to test any of these models, and the typical style of winter site excavation (testing or completely excavating only a few of the houses at a given site) and the common fashion of analysing and reporting the results (amalgamating the artifact collections from different structures at a site and then comparing the resulting assemblage with similarly constituted ones from other sites) at least partly precludes any examination of this question based on published reports.

In addition, few of the techniques that have proved fairly successful in answering culture-historical questions about the Thule are of much use in trying to deal with this sort of problem. Radiometric dating has proved to be of only limited use in dating most Thule sites, given the short span of time covered by the Thule occupation of the Arctic (which means that even dates with relatively small sigma values may span a large portion of the Thule phase) and the known problems of dating sea mammal materials and the suspected problems of dating arctic terrestrial materials (McGhee and Tuck 1976;

Park 1983: 167–8). Therefore, almost all of the chronological ordering of Thule sites that has been done has been based on the seriation of harpoon heads. There are, however, a number of problems with this. One of these is our lack of understanding of the functions of the various harpoon head types. While it is accepted that functional differences exist between at least some of the types (e.g., Taylor and McGhee 1981:51), functionality, when proposed at all, is usually ascribed on the basis of harpoon head size, given the absence of ethnographic information relating to most of the types (e.g., Mathiassen 1927:15–19; McCartney 1977:226–230). This does not, of course, account for the large amount of variability in size amongst specimens of most of the types, and necessarily leads to conclusions such as that of McCartney (1977:228, 230) who suggests that both Thule type 3 and type 4 harpoon heads were used for hunting seal, walrus and beluga. If this is so, then the long term occurrence of these rather different types needs to be explained.

The other problem, at least as important, is that the initial ordering of sites from which the harpoon head seriational sequence was developed must be considered somewhat suspect. In the absence of well-stratified sites or any means of chronometrically dating sites, Mathiassen (1927) relied heavily on his knowledge of contemporary Inuit harpoon head types, on an at least partly intuitive evolutionary scheme, and on differences in site elevation about sea level. That his typology and seriational sequence has survived as intact as it has is a tribute to its author, but it still must be acknowledged that our system of chronologically ordering sites is mostly based on "a few untested generalizations" (Taylor and McGhee 1981:51). Therefore, anyone wishing to examine problems of culture change over time within the Thule Culture, and anyone wishing to demonstrate approximate simultaneity between sites or temporal priority of one site over another, must work on a very coarse chronological scale, inappropriate for intra-site studies such as those that are needed to examine the nature of Thule winter site occupations.

Turning to specific questions of subsistence, one comes across two issues currently under debate, based on little hard evidence. One is the question of Thule whaling. Many Thule winter sites were without doubt not used by groups practising whaling locally, based on their location and other factors, but many Thule sites do appear to have been used by groups involved in whaling, and those at Porden Point appear to have been of this variety. The importance of the hunting of bowhead whales to the Thule, however, and how they carried it out, remain contentious issues (Freeman 1979; McCartney 1980). Given the probable scheduling of whale availability in this part of the Arctic (Reeves *et al.* 1983:60), and perhaps manpower constraints (McGhee 1983), whaling was probably not carried out during the part of the year when the winter sites would have been occupied so investigation of the warm-season sites may be one way to shed some light on this issue.

The other, and perhaps even more critical, subsistence practice currently being debated for the Thule is sealing, particularly breathing-hole sealing. Morrison (1983) has recently proposed that the Thule did not practice this mode of hunting, and that its initial employment signalled the end of a characteristically Thule form of adaptation and the development of the ethnographically-observed Inuit form in the Central Arctic. This idea is by no means universally accepted (e.g., Arnold 1983) and demands investigation. If breathing-hole sealing was not practiced, what was the basis of winter subsistence for the Thule? If it was practiced, how did it fit in with a settlement pattern which seems to have included winter-long occupation of coastal sites? Obviously, season of death data from Thule sites, particularly from seal remains, is extremely desirable. Recently, the analysis of season of death data from ringed seal canine teeth from Thule winter house sites in Frobisher Bay, Coronation Gulf and eastern Ellesmere Island has revealed that most of the seals were killed from spring through fall, although a few winter kills were present (Stenton 1983:152–154; Morrison 1983:266; McCullough 1986:500–503). However, ethnographic accounts from historic Inuit show that storage of food for winter consumption is very common, so one certainly can't conclude on this basis that the sites were *not* occupied during the winter. To what extent the sites were used as base camps from which hunters went out on extended hunting trips is also simply not known.

The Thule Site at Porden Point

Porden Point (76° 15′ N, 93° 40′ W) is a low gravel spit located at the southeastern corner of the Grinnell Peninsula, Devon Island, N.W.T. The archaeological sites at Porden Point were first visited by Dr. Robert McGhee of the Archaeological Survey of Canada in 1974. The Thule remains there comprise seventeen structures identified as winter houses, and over one hundred other dwelling structures of various types, presumably occupied at other times of the year. All of these are located within an area of approximately one square kilometre, while almost no others exist within a radius of over ten kilometres. In 1976 and 1977, McGhee excavated three of the winter houses as well as an isolated rock cache that contained an assemblage of Thule hunting gear. The collections deriving from these excavations were analysed as part of this researcher's master's thesis (Park 1983) and it was partly this familiarity with the material from Porden Point that resulted in this location being selected for further study.

During the summers of 1984 and 1985 the author excavated a further thirteen winter houses. Over forty dwelling structures of other types were also excavated, mostly by Rochelle Allison of this department, who is presently analysing that data. Thus, Porden Point represents one of the most completely excavated Thule sites in the Canadian Arctic, and one of the only sites where more than a minimal amount of attention has been paid to structures other than winter houses.

The importance of this approach to the excavation of the site is that a number of different techniques can be used in conjunction to try to answer some of the questions discussed above. Stylistic analysis of the artifacts is being carried out on a house-by-house basis, to attempt to assess whether all of the houses were occupied contemporaneously. This is, of course, almost impossible to do conclusively with archaeological data, and as mentioned above, our understanding of stylistic change over time for the Thule is not really sensitive enough to do this on its own in any case. However, other types of evidence will also be used, and in combination a fairly convincing argument may be made.

Differences in house style and construction are evident at Porden Point and may indicate differences in the age or nature of occupation. McGhee (1984:77–78, 90) has used stylistic differences in the winter houses at Brooman Point, Bathurst Island, to separate different periods of occupation at that site. However, he doesn't really explain why fairly dramatic changes in house form occurred over a period he estimates as less than a century, while artifact styles apparently remained fairly constant. If the results at Porden Point prove similar to his, then new attention will have to be given to the nature and rate of culture change for Thule.

Another type of structural evidence that may aid in saying something about the sequence of occupation events at the site is the bowhead whale bone found in the houses, which formerly formed the framework that supported their roofs. At least two winter houses at Porden Point appear to have essentially all of the whalebone from the roofs still present, while the others appear to have had varying amounts of the whalebone removed. This bone may have been transported to other locations, or may have been employed to build the roofs of houses built at the site after earlier ones had been abandoned. Tentatively, however, it is assumed that those houses with all of the whalebone still present were abandoned later than the others.

Analysis of the other faunal bone from the site, including the thin-sectioning of seal teeth, is also being conducted, again with the intention of trying to identify the presence or absence of differences in the nature or season of occupation of the various structures there. At the very least, comparison of the data from the winter houses and the warm season structures should provide a better understanding of actual subsistence activities during different parts of the year for the Thule, but a very preliminary analysis of the identifications completed to date suggests that significant differences may be present between some of the winter houses.

Conclusions

As stated at the beginning of this paper, the analysis of the data from the Porden Point excavations is not yet complete, and any conclusions drawn from preliminary analyses would be premature. However, the discussion presented above has hopefully demonstrated that fairly large and significant gaps remain in our understanding of the Thule Culture, gaps that may be amenable to analysis using archaeological data if the proper approaches are employed.

Acknowledgments

The 1984 and 1985 excavations at Porden Point were carried out under archaeological permits from the Government of the Northwest Territories, and with the consent of the Resolute Bay Settlement Council. The fieldwork was principally funded through research grants from the Boreal Institute for Northern Studies, with additional funding from the Arctic Institute of North America. Logistical support in the field was provided by the Polar Continental Shelf Project of the Department of Energy, Mines and Resources.

References

Arnold, C.D. 1983. Review of "Thule Culture in Western Coronation Gulf, N.W.T." by David A. Morrison. Canadian Journal of Archaeology 7(1):108–110.

Freeman, M.R. 1979. A critical view of Thule culture and ecologic adaptation. In: McCartney, A., ed. Thule Eskimo Culture: An Anthropological Retrospective. National Museum of Man, Archaeological Survey of Canada, Mercury series No. 88, pp. 278–285, Ottawa.

Mathiassen T. 1927. Archaeology of the Central Eskimos: The Thule Culture and Its Position Within the Eskimo Culture. Report of the Fifth Thule Expedition 1921–24, Vol. 4(2), Copenhagen.

McCartney, A.P. 1977. Thule Eskimo Prehistory Along Northwestern Hudson Bay. National Museum of Man, Archaeological Survey of Canada, Mercury series No. 70, Ottawa.

_____ 1980. The nature of Thule Eskimo whale use. Arctic 33(3):517–541.

McCullough, K. 1986. The Ruin Island Phase of Thule Culture in the Eastern High Arctic. Unpublished Doctoral Thesis, Department of Anthropology, University of Toronto.

McGhee, R. 1983. The Social Organization of a Thule Community. Paper presented at the 16th Chacmool Conference, Calgary.

_____ 1984. The Thule Village at Brooman Point, High Arctic Canada. National Museum of Man, Archaeological Survey of Canada. Mercury series No. 125, Ottawa.

McGhee, R. and Tuck, J.A. 1976. Un-Dating the Canadian Arctic. In: Maxwell, M.A., ed. Eastern Arctic Prehistory: Paleoeskimo Problems. Society for American Archaeology Memoir 31, pp. 6–14.

Morrison, D.A. 1983. Thule Culture in Western Coronation Gulf, N.W.T. National Museum of Man, Archaeological Survey of Canada, Mercury series No. 116, Ottawa.

Park, R.W. 1983, Porden Point and Port Refuge: Thule Eskimo Sites from the Grinnell Peninsula, Devon Island, N.W.T. Unpublished Master's thesis, Department of Anthropology, McMaster University, Hamilton.

_____ 1986. Thule Winter Houses: A Question of Definitions. Paper presented at the 19th Canadian Archaeological Association meeting, Toronto.

Reeves, R., Mitchell, E., Mansfield, A., and McLaughlin, M. 1983. Distribution and migration of the bowhead whale, *Balaena mysticetus*, in the Eastern North American Arctic. Arctic 36(1):5–64.

Stenton, D.R. 1983. An Analysis of Faunal Remains from the Peale Point Site, (KkDo-1) Baffin Island, N.W.T. Unpublished Master's thesis, Department of Anthropology, Trent University, Peterborough.

Taylor, W.E. Jr., and McGhee, R. 1981. Deblicquy, a Thule Culture Site on Bathurst Island, N.W.T., Canada. National Museum of Man, Archaeological Survey of Canada, Mercury series No. 102, Ottawa.

SEMANTICS OF CREE VERBS OF POSSESSION: PRELIMINARY REPORT OF A QUANTIFICATIONAL SEMANTIC STUDY IN NORTHERN ONTARIO

Floyd W. Rudmin

Psychology Department, Queen's University, Kingston, Ontario K7L 3N6

Level: Ph.D.

Abstract

Ownership relates people to things and people to people. Owners are attached to their property through use, familiarity, and preference, but they also are placed in a controlling, dominant, defensive posture towards non-owners. The Cree have traditionally been a socially unstratified, egalitarian people with little use for interpersonal control and dominance. Therefore, their concept of ownership is hypothesized to be quite different from that found among the socially stratified peoples typical of agricultural and industrial societies. On the basis of pilot interviews and on forward-and-back translation, 25 verbs of possession were selected for examination 1) by free-recall of the verbs from short-term memory, 2) by sorting the verbs into groups with similar meanings, and 3) by scaling the similarity of the verb OWN to each of the other 24 verbs. Subjects were 40 Cree adults from Attawapiskat on the West Coast of the James Bay. Half were unilingual in Cree and over age 40; half were bilingual in Cree and English and under age 50. The results showed that the Cree do conceive of ownership in terms of interpersonal control relationships and personal attachment relationships, but that personal components may be decreasing as a traditional part of the Cree concept of ownership.

Key words: Cree, James Bay, ownership, possession, property, semantics.

Résumé

Le droit de propriété établit une relation personnelle avec la chose possédée (p. ex.: de l'attachement, un sentiment d'utilité) et des relations interpersonnelles avec les non-propriétaires (p. ex.: une attitude de domination ou de défensive). Traditionnellement, la société crie est égalitaire et non hiérarchisée, et n'accorde guère d'importance à la domination interpersonnelle. C'est pourquoi le concept cri du droit de propriété pourrait être complètement différent de celui qui a cours dans les sociétés hiérarchisées qui caractérisent les civilisations agricole et industrielle.

En se servant des résultats d'entrevues-pilotes et de retraductions dans la langue de départ, l'auteur a choisi 25 verbes de possession à étudier: 1) par l'évocation spontanée des verbes dans la mémoire à court terme; 2) par le classement des verbes dans des groupes de significations similaires, et 3) par des évaluations linéaires de la similarité du verbe "posséder" avec chacun des 24 autres verbes. L'auteur a interrogé 40 informateurs cris adultes d'Attawapiskat, sur le littoral ouest de la baie de James. La moitié étaient unilingues cris, et avaient plus de 40 ans, l'autre moitié étaient des bilingues cris-anglais et avaient moins de 50 ans. L'auteur a effectué des comparaisons entre les résultats des analyses des groupes matriciels de similarité pour chacune méthode psycholinguistique et les a rattachés aux entrevues, aux observations sur place et aux rapports ethnographiques. Les observations ont montré que les Cris conçoivent fondamentalement le droit de propriété du point de vue des rapports interpersonnels de possession et d'attachement personnel, mais que les facteurs personnels perdraient de leur importance en tant qu'éléments traditionnels du concept cri de la propriété.

Mots-clés: Cri, baie de James, droit de propriété, possession, propriété, sémantique.

Introduction

The meaning of ownership, in terms of both psychological motivations and societal functions, has been one of the most enduring topics in the history of social science. Aristotle was the first to examine ownership in a systematic way. Within his coherent system of metaphysics, politics, ethics, and psychology (Barker, 1952), ownership of property is universal because self-actualization and self-love are universal. Also, private property is necessary to provide the leisure and economic base for the contemplative development of rationality and for participation in the political life of the community. Aristotle briefly surveyed the systems of property in several societies, including Athens, Sparta, Crete, Carthage, Thessaly, Miletus, Thebes, and Thrace. His discussion of ownership among people who are independent and acquire their sustenance directly (e.g. nomads, robbers or pirates, fishermen, hunters) also led to a consideration of eco-cultural factors in human behavior generally (Mathie, 1979):

> These natural or independent ways of life are explicitly compared with the variety of modes of nurture among animals, implying that the lives of men differ in accordance with the food they seek just as the solitary or herd-living propensities of various animal species differ in accordance with the source of nurture set out for each by nature. Those engaged in these ways of life seek and obtain self-sufficiency without entering into retail exchange; if necessary such men combine these pursuits.
>
> (Mathie, 1979, p.20)

In the millennia following Aristotle, the scholarly discussion of ownership and property has been diverse indeed. One major focus of interest has been to discover the fundamental meaning and functions of property by examining it in the state of nature, prior to modern civilization. Locke (1690/1952) and Rousseau (1755/1964) theorized on what property relationships must have been like at the beginnings of civilization, and began making references to the customs

of the Native Peoples of North America. This effort to explain ownership by reference to the customs of non-Europeans progressed from the social theorists (Engels, 1884/1902; Ensor, 1844; Marx, 1877/1954; 1972; Morgan, 1878), to the French comparative sociologists (Guyot, 1895; LaFargue, 1890; Laveleye, 1878; Letourneau, 1892; Lewinski, 1913; Petrucci, 1905), to social psychologists (Beaglehole, 1932; 1935; Drever, 1917; Duprat, 1903; Ellwood, 1927; Hobhouse, 1906; 1915; 1922; Leenhardt, 1952; Rivers, 1932). Within the theorizing of turn-of-the-century Darwinism, children were also considered to be in a pre-socialized state of nature. Therefore, the origins of property were also sought in studies of child development. Most psychological research over the past century on ownership and property has been in child development (Rudmin, 1986). Finally, there are extensive literatures on property within anthropology and comparative law (e.g. Hallowell, 1943; Herskovits, 1940; Hoebel, 1966; 1968; Lowie, 1928, 1943; Malinowski, 1926; Mead, 1937; Pospisil, 1971).

Thus, there is a very long tradition in the social sciences of trying to explain property by reference to its origins in cultural evolution and in individual development and behavior. More importantly, the property concepts and practices of North American Native Peoples have played an inordinately large role in the development of our modern theories of property (Bidney, 1954), particularly considering Locke in the liberal, capitalist ideology and Marx in communist ideology. Ironically, the welfare, culture and very existence of the larger industrial-commercial societies and the local native societies are both threatened by our present conceptions and misconceptions of property. On the one hand, for the Native Peoples, property and ownership are central concerns in their efforts to negotiate land settlements and regain control of their culture and resources within their traditional territories (e.g. Feit, 1980; 1982). Native Peoples have too long had to contend with the myth that aboriginal peoples did not traditionally have a sense of ownership. Even though this has long been repudiated by anthropologists (Burgess, 1945; Davidson, 1928; Speck 1915; 1923), Native Peoples continue to face it, for example, in the James Bay negotiations (Richardson, 1975) and in the current struggles of the Innu in Labrador and the Haida in the Queen Charlottes. One Quebec Cree council has even commissioned their own anthropological study of their traditional concepts of property and ownership. For larger national societies, on the other hand, there is the present risk of nuclear annihilation because they are divided East vs. West over ideological disputes about the function and role of private property. Liberal and Marxist property ideologies rest in large part on centuries old myths about the nature of property among aboriginal peoples, particularly those of North America.

Even though the property concepts and practices of Native Peoples are important, they have rarely, if ever, been the subject of quantified, empirical study. Most studies have been ethnographic. Certainly, none have examined the semantics of ownership using the methods of quantificational psycholinguistics similar to those of Rapoport and Fillenbaum (1972) and Takane (1980) in English and Wagener and Pohl (1986) in German. The present study attempted such an examination of Cree concepts of ownership.

Existing psychological research suggests that two important components of ownership are the owner's attachment to their property and the owner's dominance and defensiveness towards the non-owners: 1) owners are attached to their property through familiarity, use, and other personal sentiments, yet 2) owners dominate non-owners through the defense and control of their property (Ellwood, 1927; Furby, 1978; Hobhouse, 1906; 1922; Lattke, 1936; Rudmin & Berry, in press; Titchener, 1911; Veblen, 1898). It is the latter social power aspect of ownership that is of interest for this present research. It is hypothesized that the dominance component of ownership might be a manifestation of social dominance generally. If a people has a major interest in controlling one another, then possession, ownership, and property should be valued institutions and ownership should be defined more in terms of interpersonal dominance and less in terms of familiarity, utility or attachment.

Three recent studies seem to support this. First, when the language acquisition data of toddlers from four societies (Brown, 1973) were examined in relationship to measures of societal dominance (Hofstede, 1980), it was shown that the societal Power-Distance Index (PDI) was a better predictor (tau = .63) of the frequency of use of possessive case by toddlers than were sex, age, or linguistic maturity (Rudmin, 1985). Thus, the more a society values interpersonal dominance, the more its children use expressions of possession. Second, for large samples of male university students, ecological correlations of 15 societies showed a strong positive relationship ($r = .80$) between favorable attitudes towards private property and preferences for values of dominance and non-conformity (Rudmin, 1987a). Third, using responses from 238 Canadian adults and controlling for social desirability, it appears that the more assertive a person is, then the more ownership is conceived as territoriality (CLAIM, CONTROL, KEEP) and as covetness (DESIRE, WANT, NEED, CHERISH), and the less ownership is related to social value (MANAGE, DESERVE, BE FAMILIAR WITH, PLAN, SHARE) (Rudmin, 1987b). Other evidence of a positive relationship between ownership and interpersonal dominance has been provided by Ardrey (1966), Charlesworth and La Freniere (1983), Ellis (1985), Kummer (1973), Laborit (1978), and Minter (1974).

The Cree are most appropriate for examining the relationship between interpersonal dominance and ownership because they have traditionally been an egalitarian people, with little interest in controlling one another. However, this unstratified society is facing continuing acculturative pressures from the larger stratified Canadian society. The Cree are a subarctic, hunting-gathering, Algonkian people, residing primarily in northern Quebec and Ontario. Further westward, Cree may be known as Ojicree or Ojibwa. They have been the subject of numerous ethnographic studies (Bishop, 1972; 1974; Brightman, 1981; Burgess, 1954; Cox, 1970; Darnell, 1981; Drage, 1982; Dunning, 1959; Hallowell, 1949; Hanks, 1982; Hoffman, 1961; Honigman, 1948; 1953; 1956; 1958; 1968; 1981; Judd, 1982; Kehoe, 1980; Knight, 1969; Landes, 1937a; 1937b; 1937c; Molohon, 1982; Morantz, 1982; Preston, 1975; Richardson, 1975; Rogers, 1965; 1983; Rossignol, 1939; Scott, 1982; Skinner, 1911; Speck, 1915; 1923; Stallcop, 1972; Turner, 1977; Winterhalder, 1981). The traditional Cree lifestyle was based on a seasonal cycle of isolated winter hunting in small nuclear family or kin groups and summer congregation at central coastal or waterway community sites (Honigman, 1949; 1981; Judd, 1982; Leacock, 1955). Although they have

had contact with European cultures since the opening of the Hudson Bay for fur trading in the 18th century (Hallowell, 1949; Hanks, 1982; Morantz, 1982), the Cree communities have experienced relatively little acculturative pressure until the last two or three decades (Honigmann, 1948; 1981; Molohon, 1982). Within traditional Cree society, private ownership of land was well established, but did not include the commercial transfer of title (Burgess, 1945; Feit, 1982; Honigmann, 1948; Landes, 1937b; Richardson, 1975; Rossignol, 1939; Speck, 1923; Winterhalder, 1981). Property tended to be shared, though personally owned (Dowling, 1968). The Cree language has been well studied since the mid-19th century (Darnell & Vanek, 1973; Ellis, 1962; Faries & Watkins, 1938; Joseph, 1979; Wolfart & Caroll, 1973). In marked contrast to English, Cree is highly inflected. This means that the form a word takes depends on its grammatical context in the sentence. For example, in English, *my* and *mine* are the same word but inflected respectively for use as an adjective or as a predicate nominative. One consequence of this is that, in Cree, isolated words are not sensible. Psycholinguistic stimuli would have to be presented as full sentences.

Research Method

The site of the present research was Attawapiskat, Ontario. This is a Cree community on the West Coast of the James Bay. It has been studied anthropologically by both Honigmann (1948) and Molohon (1982). Presently, Attawapiskat has slightly over 1000 residents and the town includes a model hospital, school and air strip. Attawapiskat has had a history of efficient band administration, including prohibition of alcohol, a potato farming program, and local radio and TV stations. Community and residential dish antennae have been increasingly common over the last few years. Of particular importance for the present linguistic study is the generational linguistic division of the community (Bennett & Berry, 1986; Molohon, 1982). Those older than 40 tend to be Cree unilinguals and those younger than 40 tend to be Cree/English bilinguals. The older generation in the community apparently believes that the Cree of the younger generation lack both grammatical sophistication and a full, traditional vocabulary. They speak "easy Cree", while their elders speak "hard Cree".

The pilot investigation consisted of interviews modeled on Furby's (1978) protocol, conducted in English where possible and in Cree with the help of an interpreter. The objective was to identify terms of ownership that would be common and important in Cree, but that would also have comparable forms in languages of stratified societies (Canadian English and Japanese). Pilot study respondents were six adult Cree from Attawapiskat, three Catholic priests who had made careers of serving in the James Bay area, and a legal aid lawyer. They were asked about expressions of ownership, for enumerations of property, for definitions of ownership, for sentiments of ownership, for means of acquisition, and for ownership relations. Based on earlier research (Rudmin, 1983), 108 English verbs of possession and ownership were presented in English to two bilingual informants who identified verbs that were important in Cree conceptualizations of ownership and verbs that were not. These 108 verbs were also translated into Cree and then back-translated into English. This was done twice by independent sets of interpreters. These translations were checked by three different teachers of Cree, who also identified "hard Cree" words that might not be known by the younger generation.

In the final selection of stimuli, priority was given to terms that were important for the Cree conceptualization of ownership, that were classified as "easy Cree" and would be known to most of the community, that had greater consensus on translation, and that had clear equivalents in English and Japanese (based on two informants in that language). To keep the tasks manageable, only 24 terms of possession, in addition to *own*, were selected as psycholinguistic stimuli. These were *manage, control, keep, save, hide, protect, have, possess, deserve, claim, buy, be given, lend, share, be used to, be familiar with, make, plan, use, need, cherish, like, desire, and want.* The translation of the Cree verb phrases in syllabic script appear in Table 1. Because both Cree and Japanese are inflected languages, in all psycholinguistic tasks, these verbs were presented in the sentence form, "He _____ ed that."

Respondents were 40 Cree adults from Attawapiskat. Half of them were over 40 and were unilingual in Cree. The other half were younger than age 50, had been schooled in English, and were bilingual in Cree and English. In each generational language condition, half were male and half were female. Sessions were conducted in the individuals' homes with the assistance of an interpreter for the Cree unilinguals.

After introductions were made, three psycholinguistic tasks and two interview questions were presented. The first task was to listen to a tape in Cree of the 25 verbs of possession and to immediately recall them from memory. The second was to sort the 25 expressions, written on 3 × 5 note cards in Cree for the unilinguals and in English and Cree for the bilinguals, into groups with similar meanings. The third was to judge the similarity of *own* to each of the 24 other verbs of possession, using a 15 centimeter analog scale oriented axially so that placing a card near one self indicated similarity to *own* and placing the card distant from one self indicated dissimilarity. For the first two tasks, randomizations of stimuli were matched across the four subject conditions (bilingualism by sex). For the third task, stimuli were uniquely randomized for each subject. Finally, respondents were asked two interview questions: 1) "If a child asked you what 'own' meant, how would you explain the meaning? and 2) "Have the traditional ideas of 'owning' and 'property' changed since you were a child?"

Preliminary results and discussion

On the recall from memory of the verbs of possession, the mean number of responses was 6.8, with a range of 0 to 12. This was probably a result of the novelty of the task, reluctance in the presence of a stranger with a tape recorder, and an inherent cultural taciturnity (Darnell, 1981). Many of the recall responses were not a part of the original list of 25. In total, 44 terms beyond the original 25 were reported. Six terms were recalled adjacent to *own* more than once. These are listed here, with frequency values in parentheses: *manage* (4), *bought* (4), *possess* (3), *cherished* (3), *keep* (2), and *claim* (2).

This method of recall proximity for determining semantic similarity is based on the premise that when people recall items from memory, association bonds between items that are similar will be strong enough that recalling one item will

TABLE 1
English translations and Cree scripts of the verbs of possession studied.

He owned that.	ᐸ ᑎᐱᓇ·ᐁ·ᐃᓯ° ᐊᓂᒣᓂ°	He managed that.	ᐸ ᐅᐸᒪᑲᑕᐧ ᐊᓂᒣᓂ°
He saved that.	ᐸ ᐊᐟᑕᒋᑯ° ᐊᓂᒣᓂ°	He controlled that.	ᐸ ᑎᐯᓂᑕᐧ ᐊᓂᒣᓂ°
He kept that.	ᐸ ᑲᓇ·ᐁᓂᑕᐧ ᐊᓂᒣᓂ°	He was familiar with that.	ᐸ ᓂᓯᐩᑕᐧ ᐊᓂᒣᓂ°
He cherished that.	ᐸ ᓴᐸᑕ° ᐊᓂᒣᓂ°	He was used to that.	ᐸ ᓇᐃ·ᐊᕐ° ᐊᓂᒣᓂ°
He liked that.	ᐸ ᒥ·ᓂᓂᑕᐧ ᐊᓂᒣᓂ°	He shared that.	ᐸ ᑌᑕ·ᐃᓇᒪᐩᐸᓂᐠ ᐊᓂᒣᓂ°
He bought that.	ᐸ ·ᓐᐱᕐ° ᐊᓂᒣᓂ°	He lent that.	ᐸ ᐊ·ᐃᐊᓯ° ᐊᓂᒣᓂ°
He was given that.	ᐸ ᒥᓇᑲᓂ·ᐊᐠ ᐊᓂᒣᓂ°	He planned that.	ᐸ ·ᐊ·ᐁᓇᐟᑕ° ᐊᓂᒣᓂ°
He hid that.	ᐸ ᑲᑕ° ᐊᓂᒣᓂ°	He made that.	ᐸ ᐅᔨᑕ° ᐊᓂᒣᓂ°
He protected that.	ᐸ ᓇᓇᑲᒥᑕ° ᐊᓂᒣᓂ°	He wanted that.	ᐸ ᑕ·ᐁᓂᑕᐧ ᐊᓂᒣᓂ°
He possessed that.	ᐸ ᐳᑕᐅᓂ° ᐊᓂᒣᓂ°	He desired that.	ᐸ ᒧᐟᑌᐸᓂᑕᐧ ᐊᓂᒣᓂ°
He had that.	ᐸ ᐊᐅ° ᐊᓂᒣᓂ°	He used that.	ᐸ ᐊᐸᒥᑕ° ᐊᓂᒣᓂ°
He deserved that.	ᐸ ᑲᐧᐱᑕᒪᐟ° ᐊᓂᒣᓂ°	He needed that.	·ᐃ ᐊᐸᒥᑕ° ᐊᓂᒣᓂ°
He claimed that.	ᐸ ᐅᑎᓇᒪᐟ° ᓴᓂᒣᓂ°		

lead to recalling successive items that are similar. Thus, it would seem that by implicit, "unconscious" semantic processes, the Cree treat the concept of *own* as most similar to *manage* and *buy*. *Possess* and *cherish* were also semantically similar to *own*. Thus, in the recall task, the Cree represented both hypothesized types of ownership relationships, i.e. control of property from others and attachment to the property.

The sorting of the 25 verbs of possession (including *own*) by the 40 subjects was analyzed by complete clustering of the similarity matrix transformed into Euclidian space (Takane, 1980). Complete linkage produces compact clusters (Hartigan, 1981; Mardia, Kent & Bibby, 1979). The results of this cluster analysis appear in Figure 1. As illustrated by the cluster dendrogram, the results of the card sorting task can be interpreted as five clusterings of Cree verbs of possession: 1) acquiring, consisting of *own, be given, buy, claim,* and *deserve*, 2) controlling and managing, consisting of *possess, have, manage,* and *control,* 3) caretaking and defending, consisting of *save, keep, hide,* and *protect,* 4) preferring and being satisfied with, consisting of *cherish, like, use, want, desire,* and *need,* and 5) knowing and bonding, consisting of *be familiar with, be used to, plan, make,* and perhaps *share* and *lend.* Five bilingual Cree informants were consulted in making these interpretive cluster labels.

From this cluster analysis of the sorting task, it does appear that the Cree do conceive of ownership in terms of two major types of concepts: a) interpersonal control, i.e. acquiring, controlling and managing, and caretaking and defending; and b) personal attachment, i.e. preferring and being satisfied with, and knowing and bonding.

The third type of data were the scaled judgements of the similarity of *own* to each of the other verbs of possession on the 15 centimeter analog scale. Rank orderings of the verbs of possession by median scale scores for the 40 Cree respondents appear in Table 2. Generally, Cree as a group agreed that *own* is most closely related to concepts of control and acquisition, i.e. *possess, have, control, be given, manage, keep* and *claim. Cherish* was the only verb of personal attachment that was judged to be highly similar to *own*. It is interesting to note that *be given* as a means of acquisition was semantically closer to *own* than was *buy*. This is

Figure 1. Semantic similarity judgements by 40 Cree adults. Words with closer cluster linkage are more similar in meaning.

consistent with early reports of the importance of being given a thing for the Cree conceptualizations of ownership (Burgess, 1954; Rossignol, 1939).

When the scaling data were subjected to correlational analyses, generational differences between the older, Cree unilingual and the younger Cree-English bilinguals became evident. The following verbs were less related to *own* for the 20 young Cree with English abilities: *be used to* ($r = -.46$, $p = .002$), *make* ($r = -.44$, $p = .002$), *like* ($r = -.38$, $p = .008$), *be familiar with* ($r = -.34$, $p = .016$), *use* ($r = -.31$, $p = .027$) and *share* ($r = -.27$, $p = .043$). These verbs all reflect owners' personal attachment to their property. In this analysis, age and English schooling are confounded, since the two characteristics coincided in the sample. However, it was possible to partial out the effects of age from the effects of English schooling. When this was done, three verbs of the personal attachment type still showed a significant negative relationship with English ability: *make* ($r = -.54$, $p < .001$), *be used to* ($r = -.36$, $p = .012$), and *desire* ($r = -.35$, $p = .015$). This would suggest that the traditional Cree conceptualization of ownership, as present in the older, unilingual Cree, had a greater component of personal attachment to property than is now present in the younger, bilingual Cree. And this effect is not just a generational effect due to aging per se.

For the two final interview questions, most respondents stated that they would explain the meaning of *own* to a child by use of the concept of *possess*. The next most frequent response was to use the concept of *be one's own*.

TABLE 2
Summary of similarity judgements
Subjects were 40 Cree adults, using a 15-point scale.

	VERBS OF POSSESSION	MEDIAN SIMILARITY TO *OWN*	STANDARD DEVIATION
1	POSSESS	14.9	2.98
2	HAVE	14.8	2.88
3	CONTROL	14.7	3.06
4	BE GIVEN	14.7	3.55
5	MANAGE	14.6	6.10
6	KEEP	14.6	3.21
7	CLAIM	14.5	3.39
8	CHERISH	14.0	3.28
9	BUY	13.3	3.81
10	MAKE	12.5	6.14
11	DESERVE	11.5	6.11
12	USE	11.8	6.26
13	WANT	10.1	3.78
14	NEED	10.0	6.20
15	SAVE	9.8	3.97
16	PROTECT	9.8	6.42
17	SHARE	8.0	6.02
18	LIKE	7.8	6.47
19	DESIRE	6.5	6.05
20	BE USED TO	4.5	6.54
21	LEND	4.0	3.92
22	PLAN	2.0	6.34
23	BE FAMILIAR WITH	1.8	6.14
24	HIDE	0.5	6.36

Interestingly, several respondents stated that they would use the example of a small pet to teach ownership, since the child would have to take care of and be responsible for the pet. Other common examples of childhood property were a gift that someone had given the child, or a favorite toy. On the last question about changes in the concept of ownership over the past several decades, the most common answer by far was to discuss the material poverty of the old days, and the relative wealth of property nowadays, particularly such useful items as boat engines, snowmobiles, and household appliances. The older Cree did not romanticize the old days, although several did lament their inability to spend more time in bush camps.

In summary, this study of the semantics of Cree verbs of possession seems to concur with other psychological studies in identifying two principle components to the concept of ownership: interpersonal control and personal attachment. It appears that control is now more closely related to ownership than is attachment. However, it also appears that the importance of attachment to the concept of ownership is decreasing as a result of acculturative contact and must have been more important in the traditional patterns of thought. Further discussion and interpretation of these results await the completing of similar studies among English Canadians and Japanese.

Acknowledgements

Appreciation is extended to the Band officers and to the members of the Attawapiskat community who consented to this study. Translator-interpreters Elizabeth Gull and Jackie Hookimaw were more than helpful, in fact indispensable. John B. Nakogee provided many helpful ethnographic references. Support was provided by a Social Science and Humanities Research Council of Canada Doctoral Fellowship and by a Northern Studies Travel Grant.

References

Ardrey, R. (1966). The territorial imperative: A personal inquiry into the animal origins of property and nations. New York: Atheneum.

Barker, E. (Trans.) (1952). The politics of Aristotle. London: Oxford University Press.

Barry, H., Child, I., & Bacon, M. (1957). Relation of child training to subsistence economy. American Anthropologist, 61, 51-63.

Beaglehole, E. (1932). Property: A study in social psychology. New York: Macmillan.

— ——— (1935). Ownership and inheritance in an American Indian tribe. Iowa Law Review, 20, 304-316.

——————— (1968). Property. In D. Sills (Ed.), International Encyclopedia of the Social Sciences (vol. 12, pp. 589-592). N.Y.: Macmillan & Free Press.

Bennett, J.A.H., & Berry, J. W. (1986). The future of Cree syllabic literacy in Northern Canada. Unpublishd manuscript, Queen's University, Kingston, Canada.

Bidney, D. (1954). The idea of the savage in North American ethnohistory. Journal of the History of Ideas, 15, 321-327.

Bishop, C.A. (1972). Demography, ecology and trade among the Northern Ojibwa and Swampy Cree. Western Canadian Journal of Anthropology, 3, 58-71.

——————— (1974). The Northern Ojibwa and the fur trade: An historical and ecological study. Toronto: Holt, Rinehart and Winston.

Brightman, R.A. (1981). Cree land tenure in northeastern Manitoba. Chicago Anthropological Exchange, 14 (1-2), 70-98.

Brown, R. (1973). A first language: The early stages. Cambridge, MA: Harvard University Press.

Burgess, J.A. (1945). Property concepts of the Lac-St-Jean Montagnais. Primitive Man, 43, 1-25.

Charlesworth, W.R., & La Freniere, P. (1983). Dominance, friendship, and resource utilization in preschool children's groups. Ethology and Sociobiology, 4, 175-186.

Cox, B. (1970). Modernization among Mistassini-Waswanipi Cree – Comment. Canadian Review of Sociology and Anthropology, 7, 212-215.

Darnell, R. (1981). Taciturnity in native American etiquette: A Cree case. Culture, 1, 55-60.

Darnell, R., & Vanek, A.L. (1973). The psychological reality of Cree syllabics. In R. Darnell (Ed.), Canadian languages in the social context (pp. 171-192). Edmonton: University of Alberta Press.

Davidson, D.S. (1928). The family hunting territory in Australia. American Anthropolgist, 30, 614-631.

Dowling, J.H. (1968). Individual ownership and the sharing of game in hunting societies. American Anthropologist, 70, 502-507.

Drage, T.F. (1982). An ethnographic account of the Northern Cree, 1748. Manitoba Archeological Quarterly, 6, 1-40.

Drever, J. (1917). Instinct in man (The acquisitive tendency, pp. 187-190). Cambridge, Eng.: Cambridge University Press.

Dunning, R.W. (1959). Social change among the Northern Ojibwa. Toronto: University of Toronto Press.

Duprat, G. (1903). Morals: A treatise on the psycho-sociological bases of ethics (W. Greenstreet, Trans.). London: Walter Scott.

Ellis, C.D. (1962). Spoken Cree: West coast of James Bay. Toronto: Anglican Book Centre.

Ellis, L. (1985). On the rudiments of possessions and property. Social Science Information, 24, 113-143.

Ellwood, C. (1927). Cultural evolution: A study of social origins and development. New York: Century.

Engels, F. (1902). The origin of the family, private property, and the state (E. Untermann, Trans.). Chicago: Kerr. (Original published 1884)

Ensor, G. (1844). Of property. London: Effingham Wilson.

Faries, R., and Watkins, E.A. (1938). A dictionary of the Cree language. Toronto: The Anglican Book Centre.

Feit, H. A. (1980). Negotiating recognition of aboriginal rights: History, strategies and reactions to the James Bay and Northern Quebec Agreement. Canadian Journal of Anthropology, 1, 159-172.

——————— (1982). The future of hunters within nation-states: Anthropology and the James Bay Cree. In E. Leacock & R. Lee (Eds.), Politics and history in band societies (pp. 373-411). Cambridge: Cambridge University Press.

Furby, L. (1978). Possessions: Toward a theory of their meaning and function througout the life cycle. In P. Baltes (Ed.), Life span development and behavior (vol. 1, pp. 298-336). New York: Academic Press.

Godelier, M. (1978). Territory and property in primitive society. Social Science Information, 17(3), 399-426.

Guyot, Y. (1895). La propriété: Origine et évolution (Property: Origin and evolution). Paris: Librairie Delgrave.

Hallowell, A.I. (1943). The nature and function of property as a social institution. Journal of Legal and Political Science, 1, 115-138.

——————— (1949). The size of the Algonkian hunting territories: A function of ecological adjustment. American Anthropologist, 61, 35-45.

Hanks, C. (1982). The Swampy Cree and the Hudson's Bay Company at Oxford House. Ethnohistory, 29, 103-115.

Hartigan, J.A. (1981). P1M: Clustering of variables. In W.J. Dixon (Ed.), BMDP statistical software (pp. 448-455). Berkeley, CA: University of California Press.

Herskovits, M. (1940). The economic life of primitive peoples. N.Y.: Knopf.

Hobhouse, L. (1906). Morals in evolution: A study in comparative ethics. London: Chapman & Hall.

Hobhouse, L., Wheeler, G., & Ginsberg, M. (1915). The material culture and social institutions of the simpler people: An essay in correlation. London: Chapman & Hall.

Hobhouse, L. (1922). The historical evolution of property, in fact and idea. In C. Gore (Ed.), Property: Its duties and rights (2nd ed., pp. 1-36). New York: Macmillan.

Hoebel, E.A. (1966). Anthropology: The study of man (3rd. ed.). New York: McGraw-Hill.

——————— (1968). The law of primitive man. N.Y.: Atheneum.

Hoffman, H. (1961). Culture change and personality change modification among the James Bay Cree. Anthropological Papers, University of Alberta, 9(2), 81-91.

Hofstede, G. (1980). Culture's consequences: International differences in work-related values. London: Sage.

Honigman, J.J. (1948). Foodways in a muskeg community: An anthropological report on the Attawapiskat Indians. Ottawa: Indian Affairs and Northern Development Library.

——————— (1953). Social organization of the Attawapiskat Cree Indians. Anthropos, 48, 809-816.

——————— (1956). The Attawapiskat Swampy Cree – An ethnographic reconstruction. Anthropological Papers of the University of Alaska, 5(1), 23-82.

——————— (1958). Attawapiskat—Blend of traditions. Anthropologica, 6(First series), 57-67.

——————— (1968). Interpersonal relations in atomistic communities. Human Organization, 27, 220-229.

——————— (1981).West Main Cree. In W.C. Sturtevant (Ed.), Handbook of North American Indians. Volume 6: Subarctic (pp. 217-230). Washington, D.C: Smithsonian Institute.

Joseph, B.D. (1979). On the animate-inanimate distinction in Cree. Anthropological Linguisitics, 21, 351-354.

Judd, C.M. (1982). Mixed bloods of Moose Factory, 1730-1981: A socio-economic study. American Indian Culture and Research Journal, 6, 65-88.

Kehoe, A.B. (1980). The giveaway ceremony of the Blackfoot and Plains Cree. Plains Anthropologist, 25, 17-26.

Knight, R. (1969). Ecological factors in changing economy and social organization among the Rupert House Cree. Ottawa: Department of Secretary of State.

Kummer, H. (1973). Dominance versus possession: An experiment on Hamadryas baboons. In E. Menzel (Ed.), Precultural primate behavior (pp. 226-231). Basel: Karger.

Laborit, H. (1978). The biological and sociological mechanisms of aggression. International Social Science Journal, 30, 727-749.

LaFargue, P. (1890). The evolution of property from savagery to civilization. London: Swan Sonnerschein.

Landes, R. (1937a). The personality of the Ojibwa. Character and Personality, 6, 51-60.

——————— (1937b). Ojibway sociology. New York: Columbia University Press.

——————— (1937c). The Ojibway of Canada. In M. Mead (Ed.), Cooperation and competition among primitive peoples, (pp. 87-126).

Lattke, H. (1936). Uber das Verhaltnis von Kindern zum Eigentum. (The relationship of children to property). Bonn: Scheur.

Laveleye, E. (1878). De la propriété et de ses formes primitives (Primitive property) (G. Marriat, Trans.). London: Macmillan.

Leacock, E. (1955). Matrilocality in a simple-hunting economy (Montagnais-Naskapi). Southwestern Journal of Anthropology, 11, 31-47.

Leenhardt, M. (1952). La propriété et la personne dans les sociétés archaiques [Property and people in ancient societies]. Journal de Psychologie Normale et Pathologique, 45, 278-292.

Letourneau, C. (1892). Property: Its origins and development. London: Charles Scribner's Sons.

Lewinski, J. (1913). The origin of property and the formation of the village community. London: Constable.

Locke, J. (1952). The second treatise of government. Indianapolis: Bobbs-Merrill. (Original published in 1690).

Lowie, R.H. (1928). Incorporeal property in primitive society. Yale Law Review, 37, 551-563.

_____ (1943). Property rights and coercive powers of Plains Indian military societies. Journal of Legal and Political Sociology, 1, 59-71.

Malinowski, B. (1926). Crime and custom in savage society. London: Routledge & Kegan Paul.

Mardia, K.V., Kent, J.T., & Bibby, J.M. (1979). Multivariate analysis. Toronto: Academic Press.

Marx, K. (1954). Capital: A critical analysis of capitalist production (vol. 1). Moscow: Progress. (Original published 1877)

_____ (1972). The ethnological notebooks of Karl Marx (L. Krader, Ed. & Trans.). Assen: Van Gorcum.

Mathie, W. (1979). Property in the political science of Aristotle. In A. Parel & T. Flanagan (Eds.), Theories of property: Aristotle to the present (pp. 13-32). Waterloo, Ont.: Wilfred Laurier Press.

Mead, M. (Ed.). (1937). Cooperation and competition among primitive peoples. Boston: Beacon Press.

Minter, L.V. (1974). The effect of territoriality on dominance. Unpublished doctoral dissertation, UCLA, 1974.

Molohon, K. (1982). Notes on a contemporary Cree community. Paper presented at 14th Algonquian Conference, Quebec City, October, 1982.

Morantz, T. (1982). Northern Algonquian concepts of status and leadership reviewed: A case study of the eighteenth-century trading captain system. Canadian Review of Sociology and Anthropology, 19, 482-501.

Morgan, L. (1878). Ancient society. New York: Henry Holt.

Petrucci, R. (1905). Les origines naturelles de la propriété: Essai de sociologie comparée. [The natural origins of property: An essay in comparative sociology.] Paris: Giard & Briere.

Pospisil, L. (1971). Anthropology of law: A comparative theory. New York: Harper & Row.

Preston, R.J. (1975). A survey of ethnographic approaches to the Eastern Cree-Montagnais-Naskapi. Canadian Review of Sociology and Anthropology, 12, 267-277.

Rapoport, A., & Fillenbaum, S.N. (1972). An experimental study of semantic structures. In A.K. Romney, R. Shepard, & S. Nerlove (Eds.), Multidimensional scaling: Theory and applications in the behavioral sciences. Vol. II, Applications (pp. 93-131). New York: Seminar Press.

Richardson, B. (1975). Strangers devour the land. Toronto: Macmillan.

Rivers, W. 1932). Social organization (chap. 6). New York: Alfred Knopf.

Rogers, E.S. (1965). Leadership among the Indians of Eastern Subarctic Canada. Anthropologica, 7, 263-284.

_____ (1983). Cultural adaptations of the Northern Ojibwa. In A.T. Steegman, Jr. (Ed.), Boreal forest adaptations: The Northern Algonkians. New York: Plenum Press.

Rossignol, M. (1939). Property concepts among the Cree of the Rocks. Primitive Man, 12, 61-70.

Rousseau, J. (1964). The first and second discourses of Rousseau (R. Masters, Ed.). New York: St. Martin's Press. (Original published 1775)

Rudmin, F. (1983). Semantics of ownership: A study based on free-recall and on explicit judgements. Unpublished master's thesis, Queen's University, Kingston, Canada.

_____ (1985). Dominance and children's use of possessive case. Perceptual and Motor Skills, 61, 566.

_____ (1986). Some characteristics of Cree. Human Communication Canada, 10, 41-42.

_____ (1986). Psychology of ownership, possession and property: A selected bibliography since 1890. Psychological Reports, 58, 859-867.

_____ (1987a). Dominance, social control and ownership: Interpersonal values as predictors of attitudes towards private property. Symposium paper presented at the annual meeting of the Canadian Psychological Association, Vancouver, June, 1987.

_____ (1987b). Personality traits and the meaning of ownership. Symposium paper presented at the annual meeting of the American Psychological Association, New York City, August, 1987.

Rudmin, F., & Berry, J.W. (in press). The semantics of ownership: A free-recall study of property. Psychological Record.

Scott, C. (1982). Production and exchange among Wemindji Cree: Egalitarian ideology and economic base. Culture, 2, 51-64.

Skinner, A. (1911). Notes on the Eastern Cree and Northern Saulteaux. Anthropological Papers of the American Museum of Natural History, 9, part 1.

Speck, F. (1915). The family hunting band as the basis of Algonkian social organization. American Anthropologist, 17, 289-305.

_____ (1923). Mistassini hunting territories in the Labrador Peninsula. American Anthropologist, 25, 452-471.

Stallcop, E.A.A. (1972). A religious effigy of the Cree of Rockey Bay Reservation. Plains Anthropologist, 17, 68-70.

Takane, Y. (1980). Analysis of categorizing behavior by a quantification method. Behaviormetrika, 8, 75-86.

Titchener, E. (1911). A textbook of psychology (rev. ed.). New York: Macmillan.

Turner, D.H. (1977). Windigo mythology and the analysis of Cree social structure. Anthropologica, 19, 63-73.

Veblen, T. (1898). Beginnings of ownership. American Journal of Sociology, 4, 352-365.

Wagener, M., & Pohl, R. (1986). Property transfer and exchange value: The semantic structure of verbs of possession. Zeitschrift fuer experimentelle und angewandte Psychologie, 33, 329-341.

Winterhalder, B. (1981). Foraging strategies in the Boreal Forests: An analysis of Cree hunting and gathering. In B. Winterhalder & E.A. Smith (Eds.)., Hunter-gatherer foraging strategies (pp. 60-98). Chicago: Chicago University Press.

Wolfart, H.C., and Carroll, J.F. (1973). Meet Cree: A practical guide to the Cree language. Edmonton: The University of Alberta Press.

DÉVELOPPEMENT DES RESSOURCES LUDIQUES DANS LES LOCALITÉS CRIES DE LA BAIE JAMES, QUÉBEC 1982-1986

Diom Saganash

Sciences Sociales, Université du Québec en Abitibi-Témiscamingue, Rouyn, Québec J9X 5E4

Niveau: 1e cycle

Résumé

L'auteur trace à grands traits le processus de développement des ressources ludiques dans les localités cries de la baie de James, Québec. Les étapes cruciales de ce développement sont: l'élaboration d'un plan de développement des équipements ludiques basé sur l'évaluation des besoins et l'échelonnement des priorités; l'élaboration et la mise sur pied d'un programme de formation adapté aux besoins particuliers des Cris de la baie de James; la création d'un mécanisme de suivi au programme de formation, sous forme de séminaires et, finalement, la révision et la mise à jour d'un plan de développement, lequel a été mené à bien par les personnes formées, confirmant ainsi la prise en mains du développement des équipements ludiques par ces collectivités nordiques entre 1982 et 1986.

Cette expérience a permis de mettre en lumière certains faits et d'esquisser un modèle de développement socio-économique pour les collectivités cries de la baie de James. Ce processus sera expérimenté dans un avenir proche, sur le plan des communications avec le même auditoire. Dans l'éventualité d'un autre succès, il serait intéressant de savoir si ce modèle est transférable dans une autre culture, chez les Inuit peut-être ou dans certaines populations du Tiers-Monde.

Mots-clés: Loisir, Cri, Baie James, développement, ressources.

Abstract

This paper outlines the process of recreation resources development in the Cree communities of James Bay, Quebec. The key stages of the development were: the realization of a development plan of recreation resources which was an assessment of needs and determination of priorities; the elaboration and realization of a training program adapted to the specific needs of the James Bay Crees; the establishment of a follow-up mechanism to the training program in the form of seminars; and finally, the revision and update of the development plan, which was effectively carried out by the trained personnel, thereby confirming the ''take-over'' of recreation development by these northern communities in the period from 1982 to 1986.

The experience brought to light certain facts and produced a socio-economic development model for the Cree communities of James Bay. This process will, in the near future, be repeated in the area of communications with the same clientele. Should the process be successful once again, it would be interesting to verify if the model is transferable to another culture, such as the Inuit or Third World countries.

Key words: Leisure, Cree, James Bay, development, resources.

Introduction

Je fais partie du groupe USTIO. USTIO, c'est un groupe de chercheurs, de professionnels et d'intervenants de domaines variés qui offrent, tant aux populations nordiques qu'à la population de l'Abitibi-Témiscamingue, des services qui varient de la simple consultation ponctuelle jusqu'à l'élaboration et la réalisation de démarches globales de formation, de planification et de développement.

Ainsi, USTIO n'est pas un simple bureau de consultants mais plutôt un mini-centre de recherches, à but non-lucratif, qui se spécialise dans le développement socio-économique des populations nordiques.

À la fois généralistes et multi-disciplinaires, les interventions d'USTIO sont axées sur le développement socio-économique des populations nordiques, mais plus particulièrement à partir du développement des ressources humaines.

Ce champ d'activités émerge en fait de l'évolution d'un projet auquel j'ai eu l'occasion de participer au cours des cinq dernières années. Il s'agit du développement des ressources en loisirs dans les communautés cries de la Baie James.

Dans un premier temps, je vais essayer de vous tracer un portrait de l'évolution de ce dossier au cours des cinq dernières années, et, ensuite, je vais essayer de voir avec vous ce qui se dégage de cette expérience.

Évolution du projet

Il est maintenant bien établi que les loisirs occupent une place importante dans le cadre de vie de la plupart des sociétés modernes. Au cours des dernières décennies, une préoccupation de plus en plus grande pour la qualité de vie a amené les autorités gouvernmentales, tant fédérales que provinciales et locales, à investir de plus en plus dans le domaine du loisir. De la même façon, le développement des ressources en loisir est devenu une priorité dans le développement des communautés cries de la Baie James au tournant des années 80.

Après quelques tentatives infructueuses visant à articuler une politique de développement des ressources en loisirs et à obtenir des subventions de la part des gouvernements fédéral et provincial pour développer des ressources en loisirs, l'Administration régionale crie a demandé au Conseil régional des loisirs de l'Abitibi-Témiscamingue, de préparer un plan triennal de développement des ressources en loisir pour l'ensemble des communautés cries sur le territoire de la Baie James.

Plusieurs objectifs étaient visés par cette opération. D'abord, on voulait identifier les besoins des différentes communautés en matière de loisir ainsi que les moyens permettant de répondre à ces besoins. Inutile d'ajouter que par moyens, on référait surtout aux sources potentielles de financement (subventions et autres). On voulait également mettre en place une structure favorisant le développement des loisirs dans chacune des communautés, ainsi qu'une structure régionale supportant le travail de ces structures locales.

Par ailleurs, on voulait que le développement du loisir rehausse la qualité de vie dans les communautés. À ce titre, on émettait l'hypothèse que s'il y avait plus d'activités de loisir d'organisées, les problèmes de vandalisme, de délinquance juvénile, d'alcoolisme et de toxicomanie seraient réduits d'autant.

De plus, on voulait que ce développement des ressources en loisir se fasse en harmonie avec la culture traditionnelle crie et qu'il soit générateur d'emplois. Le plan de développement devait donc prévoir et permettre la prise en charge de leur développement en loisir par les populations concernées à plus ou moins court terme.

Une tournée de chacune des communautés a été effectuée. On a identifié les besoins dans chacune de ces communautés et on a essayé d'identifier avec les populations concernées, les ressources physiques, humaines et financières qui permettraient de répondre à ces besoins. À ce niveau, le plus difficile, c'était d'être réalistes. Evidemment, toutes les communautés voulaient avoir une aréna, un gymnase, un centre communautaire, etc... Cette réaction était d'ailleurs compréhensible, c'était écrit dans la Convention de la Baie James, et, avec tout ce qui s'était passé dans ces communautés depuis 1975 (constructions de maisons, d'écoles, de dispensaires, etc) tout devenait possible.

Quoiqu'il en soit, on a réussi, je pense, à articuler un plan triennal de développement réaliste et faisable qui proposait un certain nombre d'actions devant permettre aux communautés de se doter ressources minimales en loisir.

Toutefois, il est vite apparu que pour développer des structures et des programmes en loisir qui correspondent vraiment aux besoins, qui tiennent compte de la dimension culturelle et qui favorisent la prise en charge, il fallait d'abord et avant tout développer des ressources humaines.

On est donc passé à ce que j'appellerai la phase II du projet. L'Administration régionale crie a demandé à la Commission scolaire crie de former des coordonnateurs en loisir pour chacune des communautés. Avec la collaboration de l'Univeristé du Québec en Abitibi-Témiscamingue et du Collège de l'Abitibi-Témiscamingue, un programme de formation de niveau collégial a été élaboré. À partir du programme de technique de loisirs du ministère de l'Education du Québec, un curriculum spécifique a été préparé de façon à répondre aux besoins particuliers de la clientèle crie.

Après de longues et difficiles négociations, le programme a été accepté par le ministère de l'Éducation sur une base expérimentale, pour un an, avec une reconnaissance d'attestation d'études collégiales.

À partir de 22 étudiants intéressés, un groupe de 13 étudiants a été formé. Le programme a été dispensé par la Commission scolaire crie avec l'étroite collaboration de l'UQAT qui assumait l'encadrement général du programme de même que la coordination pédagogique. La certification était assumée par le Collège de l'Abitibi-Témiscamingue. D'une durée de 44 semaines, le programme comprenait 32 semaines de cours théoriques et pratiques qui se sont donnés à Val d'Or, et 12 semaines de stages dont 8 dans les communautés respectives des étudiants. Après évaluation, une part beaucoup plus importante aurait dûe se tenir directement sur le terrain dans les différentes communautés. Mais pour des raisons strictement d'ordre budgétaire, il a été impossible de réaliser le programme de cette façon.

Il est important de mentionner que tout au long de la formation, le plan de développement des ressources en loisir a constitué en quelque sorte la bible du programme de formation. Cela correspondait à ce qui attendait les étudiants à la fin du programme. Pour eux, c'était du concret et il était clair que c'était pour mettre non pas ce plan en particulier mais quelque chose de semblable en application qu'ils se formaient.

Un fois le programme complété, les étudiants sont retournés dans les communautés en janvier 1985. Onze étudiants se sont trouvés du travail en loisir, les deux autres dans des domaines connexes. Toutefois, vous comprendrez la difficulté pour un étudiant qui a suivi ni plus ni moins qu'un "crash course" d'un an, d'assumer le leadership du développement du loisir dans sa communauté. De plus, le plan triennal en était déjà à sa troisième année, les besoins avaient évolué, etc. On a donc mis en place une structure de suivi sous forme de séminaires qui se tiennent à raison de trois ou quatre fois par année.

On s'est donc donné d'abord comme objectif de reviser le plan de développement ensemble. Deux étudiants ont assumé la coordination de la démarche qui a récemment été complétée.

Outre la revision du plan, on discute des problèmes que chacun rencontre, on planifie la programmation régionale et à chaque séminaire, on traite plus en profondeur d'un sujet tel que la budgétisation en loisir, la programmation des activités sportives et culturelles, etc.

On peut donc avancer que le processus de prise en charge du développement du loisir est bien enclenché, et, que dans un ou deux ans, les communautés cries seront parfaitement autonomes en ce qui concerne le développement de leurs loisirs.

Quelques constats

Cette série d'interventions sur le développement du loisir dans les communautés cries de la Baie James ne constitue pas un programme de recherche en soi. Peut-être tout au plus est-ce de la recherche action. Mais, il se dégage de cette expérience quelques observations intéressantes qui méritent d'être étudiées plus en profondeur et qui pourraient possiblement être réinvesties dans d'autres secteurs du développement socio-économique des communautés cries.

Le lien direct établi entre la planification du développement socio-économique et le développement des ressources humaines apparaît intéressant. La planification du

développement socio-économique permet d'identifier les besoins de même que les ressources nécessaires pour répondre à ces besoins. Ces informations permettent ensuite d'élaborer un programme de formation concret axé directement sur les postes à combler. Il est de plus possible d'évaluer le nombre de postes potentiels, la nature de ces postes, etc. Autre avantage de ce modèle, la mise en place d'un programme de formation permet d'enclencher de façon très concrète le processus de prise en charge par rapport au secteur d'activité donné, ce qui augment également les possibilités d'implantation des propositions contenues dans le plan de développement.

Il y a donc là un embryon de modèle de développement socio-économique qui semble fonctionner pour les communautés et les entités cries et qui pourrait peut-être s'appliquer à d'autres peuples qui connaissent sensiblement les mêmes contraintes en égard à leur développement socio-économique. Je pense, par exemple, aux communautés inuites, à quelques peuples africains ou d'Amérique latine.

L'utilisation autant globale que par secteur d'activité de ce processus offre également certaines garanties que le transfert culturel des connaissances et des techniques transmises se fait selon les vues des populations concernées. La définition d'orientations de développement par les populations concernées préalablement à la formation d'une clientèle provenant de cette population, à partir d'un programme spécialement adapté aux besoins de cette clientèle, constitue une triple mesure de contrôle à cet égard.

Ces conditions amènent les intervenants extérieurs à limiter leur rôle à celui d'un traducteur qui articule et qui rend des informations et des connaissances compréhensibles et utilisables par la clientèle concernée.

Conclusion

Je crois personnellement au processus de recherche selon lequel un programme de recherche émerge d'une série d'interventions dans le milieu. Cette théorisation ou à tout le moins cette modélisation de la réalité ou de la vraie vie constitue pour moi une forme de recherche action intéressante qui a sa place dans le développement socio-économique des populations nordiques.

Devant l'urgence d'agir, alors que tout est à faire, USTIO entend poursuivre ses activités de recherches dans cette direction. Incidemment, une équipe d'USTIO compte prochainement utiliser le même processus, mais cette fois dans le domaine des communications. Une évaluation plus systématique de ces interventions sera faite à partir d'une approche plus expérimentale. De plus, USTIO entend travailler activement, à travers des projets et expériences, à l'élaboration d'un modèle d'intervention en développement socio-économique pour des populations isolées et faiblement peuplées.

'ACTION-REACTION': THE EVOLUTION OF THE NATIVE ECONOMY OF THE PAS AND NORWAY HOUSE AGENCIES: 1870–1939

Bruce Stadfeld

Department of History, Brandon University, Brandon, Manitoba R7A 6A9

Level: Bachelor's

Abstract

An examination of the Native economy of Treaty Five, for the period 1870 to 1939, reveals a number of important issues which must be addressed by Canadian fur trade historians. The decline of the fur trade after 1870 has been greatly exaggerated in Canadian fur trade historiography. While it may apply to southern agricultural areas this theory is certainly not true for the northern parts of the prairie provinces. In order for a better understanding of Native-white relations to be developed it is necessary that these non-agricultural areas be studied in a post-1870 context. The Natives' willingness and ability to adapt to fluctuations in employment opportunities, as stressed by A.J. Ray in 1974, remains the key to the Native economy for decades after the sale of Rupert's Land to Canada. Most importantly, though, a significant decline in the status of the fur trade does not occur until the 1930s. Also, the subsequent Native dependency on government subsidies should not be viewed with the negativism so often attached. Through an appreciation of the ideas postulated by M. Sahlins on the nature of aboriginal societies it can be argued that the Natives considered government subsidies to be simply an alternative source of income. Although it is impossible, in a work of this length, to present the detailed analysis which these ideas justify, it is hoped that the illumination of these significant aspects of the post-1870 fur trade will be the impetus for further study.

Key words: Treaty Five, 1870–1939, fur trade, Native-White relations.

Résumé

L'étude des conséquences du Traité Cinq pour l'économie autochtone au cours de la période 1870–1939 met en relief un certain nombre de questions importantes dont les historiens de la traite des fourrures au Canada devraient s'occuper. L'historiographie de ce commerce exagère fortement son déclin après 1870. Bien qu'il puisse être réel dans leurs parties méridionales et agricoles, il ne l'est certainement pas pour les parties septentrionales des provinces des Prairies. Il faut étudier ces régions non agricoles à la lumière des

événements postérieurs à 1870 pour obtenir une meilleure compréhension des rapports entre Autochtones et Blancs. Ce sont la capacité et la volonté des Autochtones de s'adapter aux fluctuations du marché de l'emploi qui sont restées les piliers de l'économie autochtone pendant les décennies qui ont suivi la cession de la Terre de Rupert au Canada, comme l'a souligné A.J. Ray en 1974. Il est cependant bon de souligner qu'il ne s'est pas produit de déclin notable du commerce des fourrures jusqu'aux années 1930. De même, il ne faut pas considérer la dépendance ultérieure des Autochtones à l'égard des allocations de l'État avec l'attitude négative si répandue. On peut soutenir que les Autochtones considèrent les allocations de l'État comme des sources supplémentaires de revenus, si on les envisage à partir des observations de M. Sahlins sur la nature des sociétés aborigènes. Bien qu'il lui soit impossible, dans cette brève étude, de présenter l'analyse détaillée que ces idées justifient, l'auteur espère que la mise en évidence des événements postérieurs à 1870 encourageront une étude plus poussée du commerce des fourrures.

Mots-clés: Traité Cinq, 1870–1939, commerce des fourrures, relations entre Autochtones et Blancs.

In an article published in 1978 A.J. Ray, one of Canada's foremost fur trade historians, offered an overview of the revisionist interpretation of fur trade history. Ray noted that one of the major problems with the writing of fur trade history had been that the writers had assumed a technological-determinist perspective, the result being that ". . . the Indian has been rendered as an essentially powerless figure who was swept along by the tide of European expansion without any real hope of channeling its direction or of influencing the character of the contact situation. The dominance of this outlook has meant that in most fur trade studies the Indian has been cast in a reflexive role."[1] Ray's own studies along with those of other scholars[2] have long since illustrated that the Indians actually adapted to the new economic opportunities with sound economic acumen and attempted to influence the trade in their favour as much as possible. The result has been that the misconception of the Indian being unable to react creatively to new opportunities has been laid to rest for the pre-1870 period.

Where there has been a lack of research is in the years following the sale of Rupert's Land. A study of the evolution of the trade in the post-1870 period makes it evident that an image of the Indians in a constant state of reaction is acceptable. Through an examination of the evolution of the fur trade in northern areas of the prairie provinces, where the changes were much more gradual than in the south, it is possible to illuminate the process by which the Indians adapted to the changing order and also comment on the manner in which these changes may be viewed.

In 1888 E. Dewdney, then Superintendent General of Indian Affairs, noted the flexibility of the boreal forest Indians:

> (T)he disappearance of (the bison) from the country did not affect the former (boreal forest Indians) as it did the latter class of Indians (those of the Plains), they being accustomed to live on other game, much of which still remains, and or fish, and to hunt fur-bearing animals and to dispose of the skins in exchange for the necessaries of life to the Hudson Bay Company . . .[3]

The majority of the Indians of the boreal forests, instead of migrating to agricultural areas and taking up the grub-hoe, continued to adapt, as they had been doing for centuries, to gradual economic changes. This adaptability meant a relationship of action-reaction between the local Indians and the whites, who instigated most of the economic changes. While the Indians were unable to direct the alterations in the economy, they continued to capitalize on them, while depending on the fur trade as their staple economy.

The Indians in the area bordering the rugged northern districts of Manitoba and the arable southern lands, exemplify the Indians' ability to adapt to diverse economic opportunities. The rock, timber, muskeg and lakes which lie between Cumberland House, Norway House, and Beren's River, along the northern reaches of Lake Winnipeg and Lake Manitoba, offered the Indians of the region numerous ways in which they could forge a living. The distance of approximately 250 miles spans an area of intense trading, both before and after 1870, as well as being crossed by important transportation routes. The Swampy Cree Indians who inhabit the area had access to diverse economic activities, such as fishing, tripping, lumber, trapping, construction, mining and also limited agriculture. These influences, coupled with the impact of the evolving access routes, such as the Hudson Bay Railway, single the district out as an example of the complexities of the post-1870 northern economy.

The most significant changes immediately following the end of the Hudson's Bay Company's legal monopoly came in the way of new technology and a re-ordering of the centres of management. By 1874 the York boat was quickly declining in importance in the transportation of goods between York Factory and Winnipeg. The Hudson's Bay post had ceased to be a major distribution centre for Company goods and by 1878 the headquarters were officially transferred to Winnipeg. Steam power was the latest development in transportation and the mid-1870s witnessed the introduction of the *Colville* on Lake Winnipeg and the *Northcote* on the North Saskatchewan River. After a few years of manually hauling freight across the portage at Grand Rapids, a light tramway was introduced in 1877.

These changes soon had an impact on the northern districts. In 1875 a Hudson's Bay Company employee commented on the modifications. "Cumberland is no longer an inland district, the force of circumstances having now promoted it to the unenviable position of a frontier one."[4] The changes in transportation technology, along with the restructuring of the Hudson's Bay Company's system of management had caused significant changes in the northern economy.

Free traders quickly took advantage of the end of the Company's monopoly and the increased accessibility of the northern areas of Manitoba. By 1886 the Hudson's Bay Company was reporting a major post established at the Pas by Shannon and Hartinaus.[5] By trading in a closer proximity to the Indians than the Hudson's Bay Company was, the free traders successfully competed with the well established company. The late 1880s led to frequent reports

of losses at Hudson's Bay Company posts due to the encroachment of the competition. Such was the case at Pelican Narrows, where an employee of Stobart & Company caused the Hudson's Bay Company post to report a decrease in profits.[6]

The competition, as their predecessors had done prior to the 1821 merger,[7] not only competed for the sale of furs, but also for the services of competent employees. The practice of enticing the best trained traders away from the Company was noted by one chief factor. The competition ". . . is doing us great injury by offering higher wages to some of our servants and securing some of the best-trained Indian traders in the same manner".[8] The free traders placed a high value on the family background of the Indians they attempted to woo away from the Hudson's Bay Company, because friends and relatives often influenced the selection of trading partners. Some Indians, demonstrating their entrepreneurial spirit, would operate their own business, separate from the Company and the white free traders. An Indian named Mackenzie, operating out of Prince Albert in 1886, was able to pay his fellow Indians higher wages than the Hudson's Bay Company, and also offered a greater variety of goods.[9] Indians were quite able to recognize and exploit profitable business situations in order to augment their income.

The remuneration which many Indians garnered from the increased competition was often quite significant. An example is a pair of Indians named Kennedy and Sinclair who, in 1886, were paid $1000 each, by Stobart & Company, for their winter's work. This included all expenses for moving to and from their winter quarters.[10] In comparison, Joseph Reader, Indian Agent for the Pas Agency, was paid a twelve month salary of $999.96 in 1887.[11]

In order to check the impact which the free traders were having on the northern fur trade, the Hudson's Bay Company increased the practice of employing 'runners'. Either permanent servants or Indians who worked part-time were sent to remote fur trapping areas so as to swing the bulk of the trade in the Company's favour.[12] The tactic was usually successful, though at times the costs exceeded the returns. Cumberland House reported a decrease in profits for the 1883 Outfit because the greater competition had forced the post to send runners to the Nelson River area.[13]

The Hudson's Bay Company's competitors realized a high return on their endeavours by trading light, inexpensive articles which were easier to transport than the bulkier goods. The Indians, being knowledgeable consumers, would purchase the so-called 'fancy goods', such as firearms, clothing, and cooking utensils from the free traders, who were usually closer to their camps. They would then travel to the Hudson's Bay Company posts for the heavier goods.[14] The Company's need to adapt to the new realities is evident in Superintendent Wrigley's report on his inspection of the posts in 1890. "The stock consisted mainly of old standard goods, heavy, costly, and yielding little profit. An effort should be made to import light and fancy goods on which a considerable profit can be obtained."[15] The situation is another example of the Indians of northern Manitoba continuing in a well established practice of getting the best deal they could from white businessmen.

The signing of Treaty 5, in 1875, with the Indians of northern Manitoba, and part of Saskatchewan, offered the Indians access to a new source of income; annuities. The Indians taking advantage of the increased competition, were soon drawing advances from the Hudson's Bay Company on their annuity payments. The debts were often not repaid. The post at Rapid River, in the Cumberland House District, recorded a loss of $279.30 due to unpaid Indian debts for the 1892 Outfit. Breaches such as these were occurring even after the Company had drastically reduced the amount of debt granted against annuities.[16]

The Company was well aware of the good business sense which the Indians possessed. Their constant playing of the Company against the free traders made one employee remark in 1886, that ". . . the Indians will now give their furs to the highest bidder & we need expect no special favour from them since the debt system has been practically abandoned."[17] The Indians were simply taking the fullest advantage of the new opportunities in the post-1870 northern economy.

The Indians' reactions to the evolving economy were obviously not always in the best interests of the Hudson's Bay Company, as the chief factor of Cumberland House reported in 1886:

> With the increased & ever increasing, opposition, the facilities strangers have of getting goods brought into the Country, the high prices they pay & the system they adopt of getting furs I fear it need not be expected that so many furs will be sent out of this District by us as were formerly sent when the trade was more completely in our hands.[18]

The Indians' actions conformed to a long exercised practice of adaptability. They enhanced their economic situation by undertaking the appropriate reactions. The result was that in 1892 they were still able to obtain their own subsistence from their available resources with little difficulty.[19]

Thus between 1870 and 1890 the fur trade remained the chief source of income for the Indians of northern Manitoba. The 1890s were to offer a new source of income to some bands. While fishing had always been an important supplement to their food resources, it now rose to a new prominence as a source of income. In the ten years prior to the turn of the century the Indian Agent reports frequently refer to the valuable fishing operations at places such as Grand Rapids.[20] By 1898 Indian Agent J.W. Short, of Beren's River, was voicing his hopes that this increasingly profitable industry would soon burgeon.[21]

Between 1899 and 1905 the proliferation of fishing companies on Lake Winnipeg would cause a veritable boom in the economies of many Indian bands. The entire Norway House band, by 1899, was able to find work with the Dominion Fish Company operating on Playgreen Lake.[22] The company also operated on Selkirk Island, near Grand Rapids. The local band, consisted of 23 men, 28 women and 64 children. Indian Agent Joseph Courtney, in his report of 1900, stated that because of the fish company ". . . nearly all of the Indians found employment."[23] The Indians were once again utilizing a new found opportunity.

After 1900 there was competition in the northern fishing industry. Ewing and Fryer, headquartered at Selkirk Manitoba, was operating on northern Lake Winnipeg. With a freezer at Warren's Landing,[24] located at the junction of the Nelson River and Lake Winnipeg, and a gas tug on Cedar Lake, Ewing and Fryer was in direct competition with Dominion Fish Company.[25] As of 1904 another freezer was reported at Spider Islands, thirty miles south of Warren's Landing, and also a steamer running from the former to Cross Lake.[26] The competition between the two southern based companies allowed the affected Indians to subsidize their incomes in a new manner.

The profits were quickly realized. In 1900 the Indians of the Norway House band caught 10,000 sturgeon and over 100,000 whitefish on Playgreen Lake. Sturgeon were selling for one dollar apiece while whitefish were 2.5 cents each.[27] Accepting these figures, the gross income would have been $12,500, while the total population of the band was 551. A conservative estimate of two children per family places the average family income from fishing at approximately $100. (The per capita income for Norway House Agency for 1900 was $62, while the per capita income derived from the fishing industry was $33, or 58% of their total income.) Realizing that not all of the families would have participated in the fishing industry, and that the work was seasonal, it can be assumed that the income was a significant supplement to the Indians' annual income.

Across the lake, at Grand Rapids, the Inspector of Indian Agencies, S.R. Marlatt, was complaining of the great hindrance to schooling created by the exodus of nearly all of the band to Selkirk Island during the summer months. The strong competition between the two companies afforded the Indians a good income during the summer.[28] While the men would work on the fishing boats, the women and children were often employed collecting fish oil, used as a substitute for butter and other fats.[29] By having concentrated family efforts such as this during the summer months, the Indians did not have to rely as strongly on the winter hunt.

The major reason for the sudden explosion in the fishing industry was not only an increased southern market, but also the high water which prevailed in the region for a number of years. Joseph Courtney reported in 1904 that the unusually high water of the last few years had "...restored these streams and lakes with fish, and at present they are literally teeming with sturgeon, trout, whitefish, perch and pike."[30] The reaction by the Indians was predictable. When able to, they seized the chance to subsidize their staple economy.[31]

The success of the fishing industry is indisputable. Yet this occurrence must be assessed in the context of a regionally based economy. The fishing industry did not affect all of the Indian bands to the same degree. In fact some bands were hardly affected at all. One reason for this is that the same circumstance which led to increased fish populations, high water, also favoured the musk-rats. During the peak of the fishing industry, in the early 1900s, S.R. Marlatt reported that in The Pas Agency ". . . musk-rats, the principal fur-bearing animals were very abundant, the Indians made large amounts from the catch."[32] The trade was still a very important part of many Indians' subsistence, with some catching as many as 5,000 rats a year, while they were trading at nine cents a piece.[33] This would result in a profit of $450, which would easily surpass most incomes from the fishing industry.

Following the end of the boom in fishing, approximately 1905 in the Norway House Agency, the fur trade quickly regained its prominence with almost all of the Indian bands; although a much different analysis has been recently offered by an historian studying the post-1870 northern economy.[34] Comments on the proliferation of furs at the north end of Lake Winnipeg occur in both the Indian Affairs and North West Mounted Police reports.[35] The fur trade had not really faltered, but instead had been overshadowed by the fishing industry. Now that the fishing had subsided, the fur trade reclaimed its previous role.

The Indian bands outside of the area affected by the fishing industry continued to concentrate on the available forms of employment. Removed from the two major wharfs on Lake Winnipeg, Warren's Landing and Grand Rapids, many Indians were not able to capitalize on the fishing, and so concentrated on trapping.[36] By the 1910s most of the bands were pre-occupied with trapping. In 1912, Indian Agent Fred Fischer, reported on the general economic orientation of the Indians of The Pas band. "Fishing has been greatly neglected for the fur hunt, but those living on the reserve have managed to catch sufficient for their needs."[37] The figures compiled by the Department of Indian Affairs support Fischer's assessment. By 1910 The Pas Agency was deriving 71% of its total income from the fur trade (see Table A2), while Norway House Agency, in 1914, relied upon the fur trade for 74% of its total income (see Table B2). Obviously the fishing industry was only another phase in a series of adaptations made by the Indians of northern Manitoba after 1870. As they had for the previous two-hundred years, the Indians utilized available employment in order to supplement their fur trade income. When such job opportunities were either not in a band's locality, or else filled by encroaching whites, the Indians reverted to the fur hunt.

The Pas Agency offers a good example of the differences in employment opportunities, even within a one-hundred mile radius. While the Indians near Grand Rapids were diligently capitalizing on the prosperity caused by the local wharf, bands only a few miles away were restricted to proceeds from the fur hunt. The Red Earth band, situated one hundred miles from the mouth of the Carrot River, reportedly saw few whites and were solely engaged in the fur trade during the 1890s.[38] The same applies to The Pas reserve, where, in 1897, it was "...regretted that during the entire summer months there is but little employment to be found for these Indians."[39] Because they were located outside of the concentration of southern businesses, many Indians continued with their well established economic pursuits.

The economic inconsistencies within the Pas Agency continued through the turn of the century. While the Grand Rapids band was able to make money by working on the wharf, as well as secondary services, such as selling curios to interested whites,[40] many of the other bands lacked such opportunities. The Chemawawin, Moose Lake, Shoal Lake, Red Earth, The Pas and Cumberland House bands were all reportedly restricted to traditional employment.[41]

The Beren's River Agency witnessed the same diverse economic opportunities. Prior to the fishing boom on the north end of Lake Winnipeg, the differences between the economy south of Beren's River, as compared to the north, was significant. While the southern Indians were often employed in lumber camps and mills, the ones to the north had no such opportunities. The bands located in isolated areas continued in their accepted roles until new opportunities were presented. Thus the Indians were in a constant state of reaction. They did not control or even have much influence on the decisions of the outside companies. Because of this they always had to react to outside forces if they wanted to profit from non-fur trade employment.

An example of this relationship is the tenuous hold the Indians had on non-fur trade jobs. When, in 1896, a group of southern Icelanders travelled to Grand Rapids to seek employment with the fish companies, many of the Indians suddenly found themselves deprived of their new source of income.[42] Much of the employment outside of the fur trade was open to the Indians for only as long as there were no available whites to fill the positions.

A similar situation developed in the wake of new technology. The Indians of Cumberland House had been employed in the transportation industry; canoeing, York boats, and steamers, since the first Europeans had crossed their lands. By 1900 the railway had replaced water transportation, leaving the Indians without additional sources of income.[43] The result of this action-reaction relationship between the whites and the local Indians was that the Indians were in a constant state of flux. They took advantage of opportunities when they arose, but always relied on the fur trade as an economic security against decisions beyond their control. The relationship was acceptable for as long as the fur trade remained viable.

In 1904 the Pas Indians attempted to initiate changes in their economy without the leadership of the southern whites. They requested, from the Department of Indian Affairs, a saw mill for their band. They agreed to pay one-third of the $1800 cost by putting $100 down and having $500 deducted from their next annuity payment.[44] By 1907 they had a timber reserve on the Carrot River and were processing approximately 60,000 feet of lumber a season.[45]

Although the Indians had been successful in establishing their own saw mill, their markets were often limited. The lumber was usually used to repair buildings on the reserve or in a few cases sales were made to other reserves which did not have a saw mill.[46] Profitable southern markets were not open to Indian lumber. Instead, lumber companies based in the south had moved into the timber areas. The results were certainly not entirely detrimental, as many Indians found employment with the companies. The Red Earth Indians, who had previously been unaffected by the fishing industry, suddenly found all the work they wanted with the Finger Lumber Company, located twenty miles from the reserve.[47] Yet once again the Indians were reacting to opportunities which had been initiated by outsiders.

The lumber companies were only the start of a flood of southern whites into the region prior to World War I. Drawn by either the lure of adventure, the profitable fur trade, the advancing Hudson Bay Railway, or the cry of "gold", these opportunists would alter the northern economy. By 1913 prospectors began to rush to the newly formed town of The Pas, seeking riches in the Wintering Lake district to the north. The North West Mounted Police reported thirty to forty prospectors travelling to Wintering Lake, with seventy-five claims staked.[48] Individual miners reported that ten dollars to the ton in gold and silver was being discovered.[49]

The mining, like the fishing and lumber industries, allowed local Indians to secure employment apart from the fur trade. The Cumberland House band, who had formerly been deprived of their summer work by the intrusion of the railway, suddenly enjoyed renewed opportunities owing to the mining surge. S.J. Jackson, Inspector of Indian Agencies, noted, in 1915, the role which positioning played in the increased economic activities. "This reserve is on the line of travel to the gold mines of that part of Saskatchewan (Wintering Lake), and the Indians can get a lot of work from the prospectors."[50] Once again the Indians enjoyed the increased opportunities, within the context of the fur trade. As usual they could not control the non-fur trade employment so reacted as best as they could to the changes.

Even the pursuit of agriculture fits into this relationship. While the Department of Indian Affairs had been concerned, beginning with the signing of the treaty of 1875, with educating the Indians in the joys of the grub-hoe, it was not until the Indians perceived a viable return on such exertions, that they began to find value in the effort. Writing in 1904, S.R. Marlatt assessed the reasons for the Indians not adopting an agricultural life style. ". . . (T)hey are too far from market to dispose of them (their cattle) and as a food supply to the owners, of little value in a country where moose, bear, and fish are plentiful . . . As a matter of fact, they would not raise cattle at all if it were not their desire to please the department."[51] Yet, by the 1910s the Indians were regularly selling produce, such as beef and potatoes, to the local lumber camps, prospectors and surveyors.[52] The Indians had perceived a profitable resource and had capitalized on the opportunity to exploit it.

The increased economic activity in the area brought with it some undesired results. Mining, lumbering and the building of the Hudson Bay Railway brought many characters possessing questionable morals into the blossoming town of The Pas.[53] During these formative years many questions were raised as to the effects these changes would have on the local Indians.[54] The problem was a very localized one and the Indians on the affected reserves attempted to make the most of the situation.

In 1912 two residents of the reserve were hired as officers to patrol the reserve.[55] Furthermore, after reporting in 1912 that many of the young male Indians were being subjected to the moral turpitude of the whites, due to their frequenting the town billiard hall, S.J. Jackson happily reported in 1913 that a band councillor had opened a billiard hall in the back of his house, and was successfully competing with the town's pool hall.[56] Some of the young people on the reserve who had been educated at the local day schools and later at either the Pine Creek or Norway House residential schools, took advantage of the growth of the town by obtaining clerking jobs with town merchants.[57]

The Indians of The Pas Agency again and again exhibited their ability and willingness to adapt to their changing economic environment. For many years their flexibility had allowed them to make the most of outside influences.

During the first years of the twentieth century they continued to implement these practices. As long as the fur trade remained as a basis for their economy the Indians could continue to cope with the shifts in their secondary income which were beyond their control. The changes, though, as Lake Winnipeg Inspector John Bunn ominously predicted in 1915, were to be greater than ever before:

> In this agency (Norway House) there is a new factor present in the development of this part of the country; I refer to the Hudson Bay Railway, and the construction and building of this great work now going on. In one way it has been a benefit to the Indians, as in the early stages of location and construction, it has furnished work to many Indians, for which they were well paid; on the other hand, the advent of this development will be accompanied by conditions that will be of doubtful benefit to the Indians; as the work of the railway building reaches completion, there will no doubt be a movement into the country of settlers and white hunters, and then the problem of caring for the Indians will assume a more complex aspect.[58]

The Hudson Bay Railway had long been a topic of political discussion in Manitoba. Calls for a rail link between Winnipeg and the Bay were expressed as early as the 1870s. Real progress was not made on the hoped for route until the late 1890s. The amalgamation of Lake Manitoba Railway and Canal Company with Winnipeg and Great Northern Railway Company, to form the Canadian Northern Railway Company, brought the rail as far north as Dauphin in 1896. By 1908 the transportation route had reached Prince Albert and a branch line from Hudson Bay Junction, in Saskatchewan, to The Pas had been laid. By the time World War I had commenced, a bridge had been built over the Saskatchewan River at The Pas and track had been laid in the direction of Hudson Bay.[59] The rail had reached Kettle Rapids, one-hundred miles from the planned terminus at Port Nelson, when the construction was halted, owing to the need for steel and men in the war effort.

Political and financial difficulties would prevent the railway's completion until the late 1920s, yet the construction had already affected the Indians of the region. The surveying parties and the cutting of the right of way provided the surrounding Indians with employment. As early as 1900 government officials in The Pas Agency were commenting on the many local opportunities[60] Optimism predominated in the region during the early construction. Joseph Courtney expressed the opinion of the whites in the area. ". . . (W)ith the advent of the railway . . . we expect that not only the cattle but many other latent industries will be opened up . . ."[61] The increased accessibility could only benefit the northern economy.

As of 1909 the benefits of the railway had reached Norway House Agency, where the surveying excursions provided the Indians with a great deal of work.[62] The Indians, as they had been doing for generations, secured work which they were judged to be best suited for. Guiding, canoeing and the provision of supplies, such as game and potatoes, enabled the indigenous population to supplement their staple source of income.

The railway, in many ways, had the same effect as the various economic opportunities which it succeeded. Whether they were transporting goods, operating as middlemen, capitalizing on the fishing industry or earning wages from guiding, the Indians had always been able to make the most of their situation. The Hudson Bay Railway readily complied with this tradition. Yet its passing was, in some ways, much more significant because it made the area more accessible to southern businesses and workers. In 1916 Indian Inspector S.J. Jackson predicted the changes to come. "The Hudson Bay Railway will make access to this reserve (The Pas) easier in the future . . . and when it is in operation, there will be no difficulty in getting into or out of that reserve at any season of the year . . ."[63] The actual building of the railway provided the Indians with extra income; the end result though was to contribute to their weakening economic position.

Although the end result was foreseeable, the effect of the railway would have to be first coupled with a major alteration in the Indians' traditional source of income before it would have a dramatic impact. The building of the railway was not renewed until agrarian protest of the 1920s, headed by the Progressive Party, forced William Lyon Mckenzie's government to act. By 1929 the remaining three hundred miles of track to the newly chosen port of Churchill were laid. The last spike was driven on April 3 and the railway was ready for use by September.

The completion of the railway, because it coincided with the gradual decline of the northern fur trade, was an epoch in the evolution of the northern economy. Beginning in 1920, for both The Pas and Norway House Agencies, the value of the hunt, which included fur trade profits, in the Indians' total profits began a steady decline. Fluctuations in the importance of the hunt had occurred in previous years because the Indians were often capitalizing on different economic opportunities. Before the 1920s, it had always been either fishing or wages which had caused a decline in the importance of the fur trade (see tables A1 and B1). By the 1930s, this was no longer so. Instead government subsidies, including annuity payments and relief funds, had assumed a precedent setting importance.

A close study of the tables illustrates the plight of the fur trade between 1897 and the late 1930s. The fluctuations in The Pas Agency typify the changing employment opportunities. Between 1897 and 1916 the fur trade had continually accounted for a large portion of the Indians' income, while fishing, wages and the sale and consumption of produce constituted the majority of the balance. The value of government subsidies had never been more than that of the hunt. Yet, by 1938 the importance of government subsidies had risen to 40.3%, while the hunt's share of the total income was 25.3%. The fur trade had ceased to be the primary source of income for the Indians of The Pas Agency. Whereas they had formerly turned to various sources of income, the Indians now relied upon government subsidies.

The Norway House Agency also underwent significant changes. The value of the hunt at the turn of the century was only 9.9% (see Table B2). The reason for this, like The Pas Agency, was that the Indians were busy profiting from the fishing industry. The value of income derived from fishing was 59%. The Indians had simply turned to another available source of income. The value of government subsidies

TABLE A1
The Pas Agency Native Economy

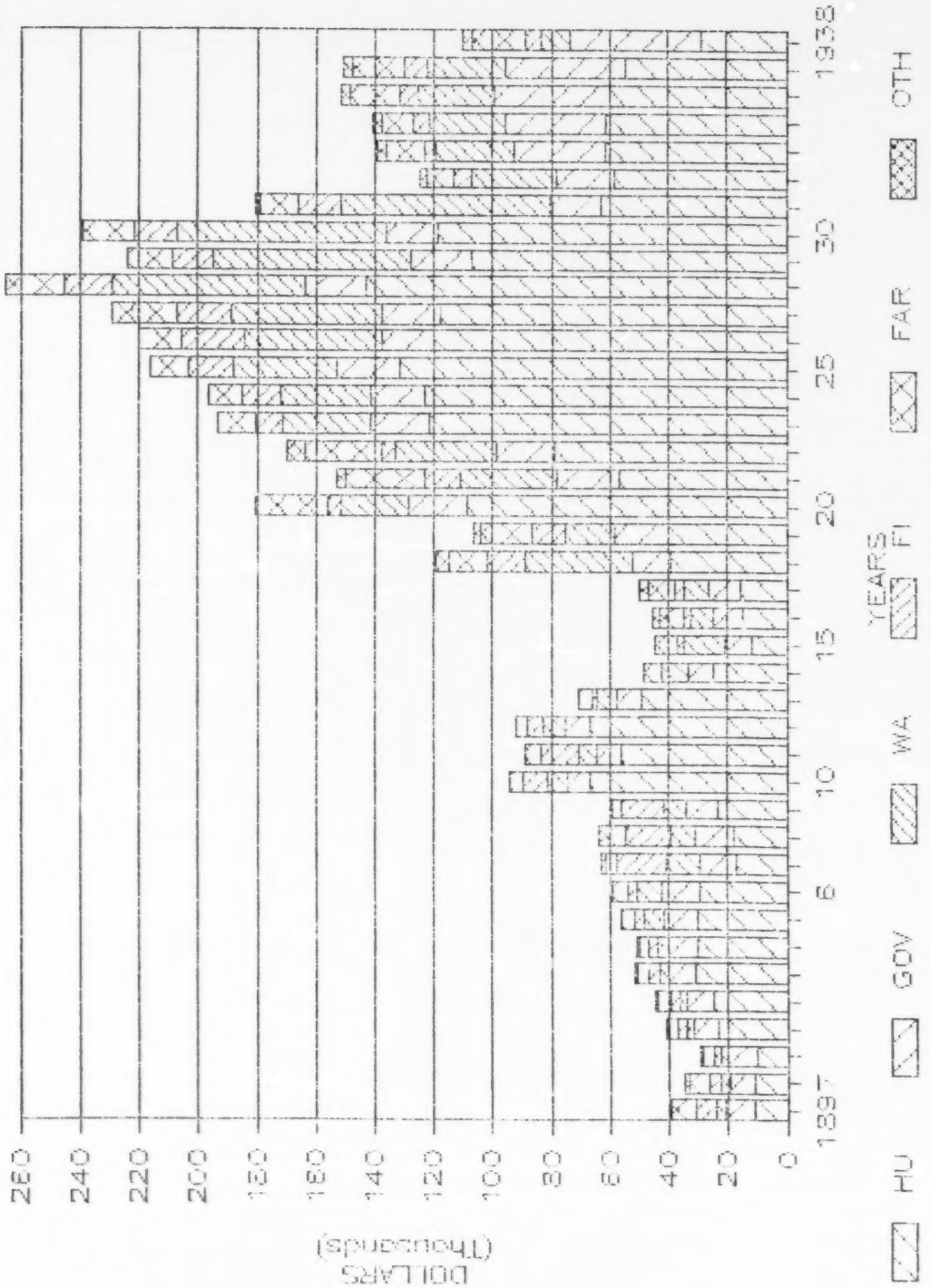
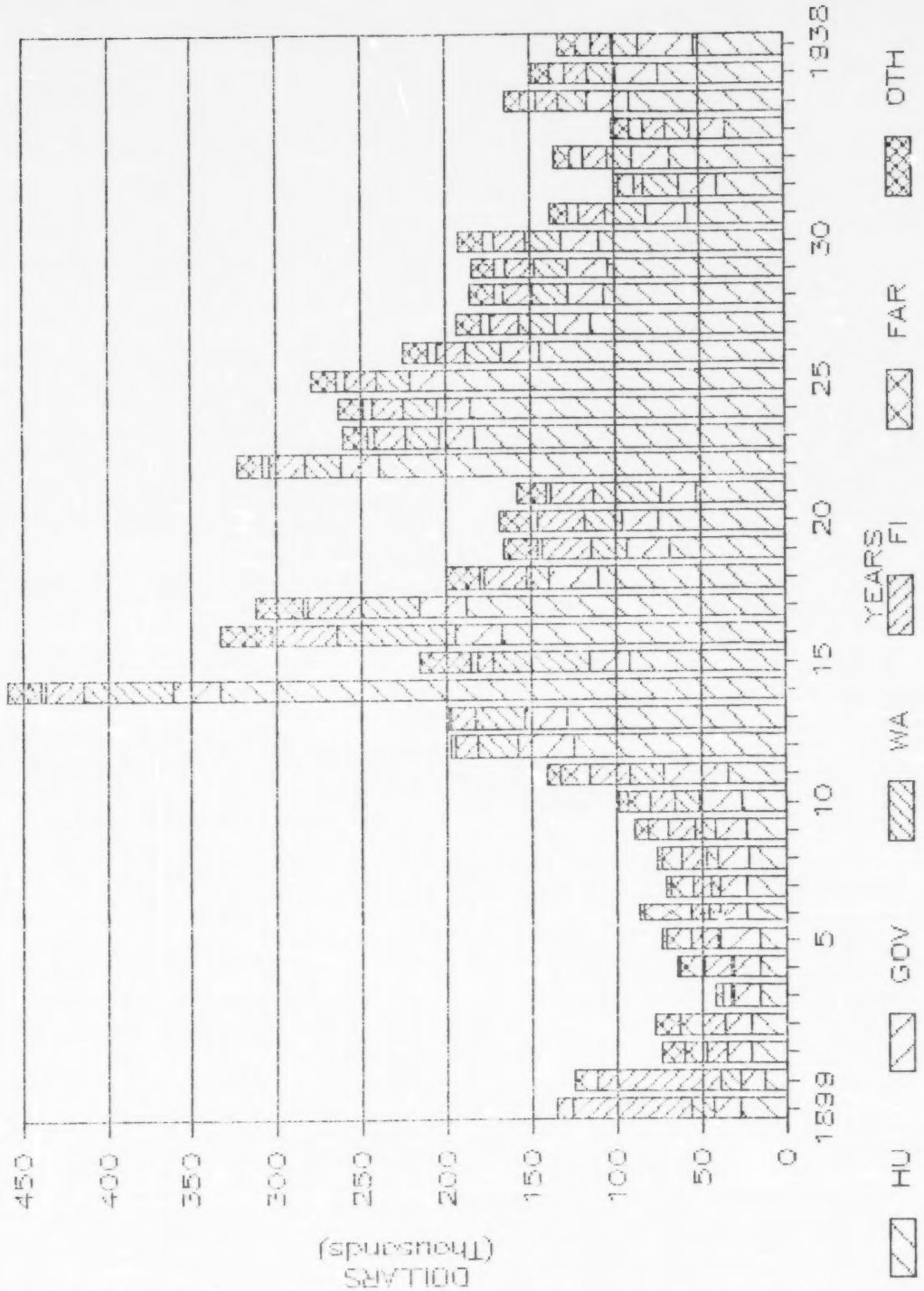


TABLE B1
Norway House Agency Native Economy



Index to Graphs

Graphs A1 and B1 illustrate the sources from which the Indians of The Pas and Norway House Agencies derived their income.

GOV = Government subsidies; including all money paid out for annuities and relief.

HU = All the money which the Indians made from the trading of furs as well as an estimate of the value of the game which they consumed.

WA = Their wages from full and part-time jobs (Excluding the fishing industry).

FI = Is the amount of money they received from the sale of fish as well as working for the fish companies.

FAR = Is the total of the income from farm produce as well as timber lease revenues.

OTH = Is the Indians' income from other sources.

The statistics for the year 1937 are unavailable for both agencies, while 1905 is unavailable for The Pas Agency. Also the statistics were not kept before 1897 for The Pas Agency and are not useful before 1899 for Norway House Agency.

Source: Department of Indian Affairs Annual Reports.

vacillated between 6 and 37 percent. The reason for the importance of government subsidies in 1904 was that the fishing industry had ceased to hold an important role, and the fur trade had not yet rebounded to offset the loss. By 1912 the value of the hunt had sky-rocketed and government subsidies had returned to their subordinate position. During the 1920s the importance of the hunt began to decline while the importance of government subsidies increased.

The foundations of the Indian economy had undergone a gradual, yet drastic change. While the Indians had formerly found adequate secondary employment in local industries, they were now forced to travel south for seasonal work. In 1936 the Department of Indian Affairs reported that a great many Indians from around Lake Winnipeg and Lake Manitoba were travelling south in the summer to work on farms.[64] These changes coincided with the depletion of fur-bearing animals in northern Manitoba. In 1938–1939 the Manitoba government paid $32,450 for fur conservation, this is compared to Quebec, Alberta and British Columbia whose combined payment was only $4,860.[65] Obviously the need to revitalize the fur trade was of prime importance in Manitoba.

Thus by the 1930s the economy of The Pas and Norway House Agencies had suffered unprecedented changes. In 1938 Dr. H. McGill, Director of Indian Affairs Branch of the Department of Mines and Resources, commented on the situation:

> The muskrat has in the past contributed generously to the welfare of the Indians, and steps are being taken to restore these animals in their former hundreds of thousands to the wholly depleated(sic) area. The method employed is conservation and control of adequate water supplies coupled with strict supervision. The employment provided by development work, consisting of the construction of canals, dams and dikes, has greatly benefitted the resident population and has already noticeably reduced the amount of relief which it has been necessary in the past to give these needy bands. The project opens an avenue of hope to substantial groups of people who in twenty years have seen their chief means of livelihood disappear under the stress of drought and white encroachment.[66]

Although this comment pertains directly to The Pas Agency, the tables clearly illustrate that similar circumstances were affecting the Norway House Agency. A gradual alienation of the Indians from their staple source of income, as well as the decreased opportunities for secondary industries had left the Indians dependent to a greater degree than ever before on government subsidies. Ironically, by securing employment in the building of the renewal system, which would hopefully re-establish their traditional source of income, the Indians were once again exemplifying their ability and willingness to capitalize on any opportunities.

The evolution of post-1870 economies of The Pas and Norway House Agencies undermines any assertion that the fur trade ceased to play an important role in the Indians' economy after 1870. In fact, the study proves that any attempt to choose a specific date as the 'turning point' is simplistic. Instead the complexities of the northern economy and the willingness of the Indians to accommodate gradual, and also dramatic changes, indicate the need for a more comprehensive assessment. The Indians always reacted to alterations in their economy with the most astute economic sense. When extra income was available they used it to augment, or at times replace, the fur trade industry. At the same time, the fur trade was always there to support them when there was nothing else. By the 1930s this was no longer the case. Secondary employment had been largely assumed by whites, and the fur trade was faltering. At present the precise circumstances leading to this change are unclear. What is clear though, is that the 1930s situation can be largely attributed to the Indians' ability and willingness to constantly react to their evolving economy, while possessing less and less control over their destiny.

While outlining the state of fur trade historiography in 1978 A.J. Ray voiced the opinion that research into the post-1870 period could possibly draw a picture which ". . . shows the Indians to be innovative, dynamic and responsive people, whose creativity and initiative have been thwarted . . ."[67] Research shows that the Indians did in fact exhibit the very traits which Ray predicted they might. Yet Ray too readily evokes the image of the Indians being tied to the reserves and controlled by the government. It is vital to a sharper picture of Indian society to realize that their creativity was not simply thwarted by external forces. Statements such as Ray's cast an ethnocentric mirage over the Indians'economic responses. A more acceptable perspective is to view the Indians' dependency as a logical and creative response to decreasing economic opportunities.

References

1 Ray, A.J. "Fur trade history as an aspect of native history", in One Century Later: Western Canadian Reserve Indians since Treaty 7, edited by Ian A.L. Getty and Donald B. Smith, Vancouver: University of British Columbia Press, 1978. p. 104.

2 For examples of the more recent historiography on the northern fur trade see, Coates, K. "Furs Along the Yukon: Hudson's Bay Company-Native Trade in the Yukon River Basin, 1830–1893", B.C. Studies, 55:50–78, Autumn 1982; Francis, Daniel & Toby Morantz, Partners in Furs, Toronto: University of Toronto Press, 1983; Krech, Shepard III, ed., The Subarctic Fur Trade: Native Social and Economic Adaptations, Vancouver: University of British Columbia Press,

1985; J.C. Yerbury, The Subarctic Indians and the Fur Trade, 1680–1860, Vancouver: University of British Columbia Press, 1986.
3 Department of Indian Affairs, 1889, Report, Superintendent General (hereafter DIA., 1889 Report, Superintendent).
4 Hudson's Bay Company Archives, B.49/E#7, (hereafter HBCA., B. 49/E#7).
5 HBCA., B.49/E#10.
6 HBCA., B.49/E#10.
7 The Nor-West Company, based in Montreal, often acquired the services of some of the Hudson's Bay Company's best employees. For more information see A.J. Ray, Indians in the Fur Trade, Toronto: University of Toronto Press, 1974.
8 HBCA., B.49/E#10.
9 HBCA., B.49/E#10.
10 HBCA., B.49/E#10.
11 DIA., 1888 Report, Expenses.
12 HBCA., B.154/E#13.
13 HBCA., B.49/E#10.
14 HBCA., B.49/E#9.
15 HBCA., B.154/E#21.
16 HBCA., B.49/E#19.
17 HBCA., B.49/E#10.
18 HBCA., B.48/E#10.
19 DIA., 1892, Report, Superintendent General.
20 DIA., 1894, Report, The Pas Agency.
21 DIA., 1899, Report, Beren's River Agency (The Agency's name was changed to Norway House as of 1904).
22 DIA., 1900, Report, Lake Winnipeg Inspectorate.
23 DIA., 1900, Report, The Pas Agency.
24 DIA., 1904, Report, Lake Winnipeg Inspectorate.
25 DIA., 1904, Report, Lake Winnipeg Inspectorate.
26 DIA., 1905, Report, Lake Winnipeg Inspectorate.
27 DIA., 1904, Report, Lake Winnipeg Inspectorate.
28 DIA., 1904, Report, Lake Winnipeg Inspectorate.
29 DIA., 1901, Report, Lake Manitoba Inspectorate.
30 DIA., 1905, Report, The Pas Agency.
31 DIA., 1902, Report, Beren's River Agency.
32 DIA., 1903, Report, Lake Winnipeg Inspectorate.
33 DIA., 1902, Report, Lake Winnipeg Inspectorate.
34 In his article entitled "Changes to the Native Economy of Northern Manitoba in the Post-Treaty Period: 1870–1900", Native Studies Review, 1:40–66, 1984; Frank Tough asserts that the major reason for the change in the Indian economy was that the Indians were now forced to adapt to a 'reserve-based' environment, and that the concentration on fishing at the turn of the century marked the end of the primary importance of the fur trade. The Indians were not restricted to their reserves, as the many complaints from Indian Agents over the low attendance at day schools suggests, and the fishing boom was merely a passing phase as the rest of this essay will illustrate.
35 DIA., 1905, Report, Lake Winnipeg Inspectorate and North West Mounted Police, 1906, Report, Lake Winnipeg Patrol.
36 DIA., 1911, Report, The Pas Agency.
37 DIA., 1913, Report, Lake Manitoba Inspectorate.
38 DIA., 1893, Report, The Pas Agency.
39 DIA., 1889, Report, The Pas Agency.
40 DIA., 1899, Report, Lake Winnipeg Inspectorate.
41 DIA., 1899, Report, Lake Winnipeg Inspectorate.
42 DIA., 1897, Report, The Pas Agency.
43 DIA., 1901, Report, Lake Manitoba Inspectorate.
44 DIA., 1905, Report, Lake Manitoba Inspectorate.
45 DIA., 1908, Report, The Pas Agency.
46 DIA., 1910, Report, The Pas Agency.
47 DIA., 1915, Report, Lake Winnipeg Inspectorate.
48 NWMP., 1914, Report, Superintendent W.H. Routledge.
49 NWMP., 1914, Report, Churchill Report.
50 DIA., 1916, Report, Lake Winnipeg Inspectorate.
51 DIA., 1905, Report, Lake Manitoba Inspectorate.
52 DIA., 1914, Report, The Pas Agency.
53 DIA., 1912, Report, Lake Manitoba Inspectorate.
54 DIA., 1916, Report, The Pas Agency.
55 DIA., 1913, Report, Lake Manitoba Inspectorate.
56 DIA., 1914, Report, Lake Manitoba Inspectorate.
57 DIA., 1917, Report, The Pas Agency.
58 DIA., 1916, Report, Lake Winnipeg Inspectorate.
59 For a brief summary of the building of the Hudson Bay Railway see, The Hudson Bay Railway, Manitoba Historic Resources Branch, 1982.
60 DIA., 1901, Report, The Pas Agency.
61 DIA., 1907, Report, The Pas Agency.
62 DIA., 1910, Report, Norway House Agency.
63 DIA., 1917, Report, Lake Manitoba Inspectorate.
64 DIA., 1937, Report, Director's Report.
65 DIA., 1939, Report, Director's Report.
66 DIA., 1939, Report, Director's Report.
67 A.J. Ray, "Fur Trade History as an Aspect of Native History", in One Century Later: Western Canadian Reserve Indians since Treaty 7, edited by Ian A.L. Getty and Donald B. Smith, Vancouver: University of British Columbia Press, 1978 p. 114.

PREHISTORIC INLAND ADAPTATIONS IN SOUTHERN BAFFIN ISLAND, N.W.T.

Douglas R. Stenton

Department of Anthropology, University of Alberta, Edmonton, Alberta T6G 2H4

Level: Ph.D.

Abstract

Although recognized to be an integral dimension of the annual settlement and subsistence cycle, the dynamics of prehistoric terrestrial resource use by arctic coastal-marine hunters remain poorly understood due to limitations associated with the archaeological record. Historically, the most intensive period of terrestrial resource harvesting occurred during the summer and fall months, involved variable procurement strategies, and small, highly mobile hunting groups. Arctic archaeologists have generally neglected the material record produced by this behaviour, largely due to small site size and poor artifact yield. Published accounts dealing with southern Baffin Island, however, indicate the Nettilling and Amadjuak lakes region once figured prominently in the seasonal round of groups inhabiting three distinct coastal areas (Hudson Strait, Frobisher Bay and Cumberland Sound).

Field and archival research integrating diverse information sources (ethnographic, archaeological, ethnohistoric, biological and paleo-environmental) provides conclusive evidence of the importance of the Nettilling region extending back some 3000 years, and changing patterns of land use through this period.

Key words: Baffin Island, archaeology, ecology, land use patterning.

Résumé

On sait que le cycle d'utilisation des ressources terrestres par les chasseurs préhistoriques du littoral et de la mer arctiques constituait une caractéristique fondamentale de leur subsistance et de leur migration annuelle, mais on comprend mal sa dynamique, à cause de la pauvreté des gisements archéologiques. La période de chasse intense de la faune terrestre se plaçait en été et en automne; de petits groupes de chasseurs, très mobiles, y participaient en utilisant des techniques de chasse très diverses. Les archéologues de l'Arctique ont, en général, négligé les preuves matérielles de ce comportement, à cause du faible nombre d'objets façonnés et de la faible superficie des sites. Les exposés publiés au sujet de la partie méridionale de l'île de Baffin indiquent cependant que la région des lacs Nettilling et Amadjuak figurait autrefois largement dans la migration saisonnière des groupes habitant dans trois zones littorales distinctes (détroit d'Hudson, baie de Frobisher et passage de Cumberland).

Les recherches de l'auteur dans les archives et sur place lui ont permis de grouper les renseignements provenant de diverses sources (ethnographique, archéologique, ethnohistorique, biologique et paléoécologique) et fournissent des preuves de l'importance de la région du lac Nettilling pour les Autochtones depuis 3 000 ans, et des changements de l'utilisation des terres au cours de cette période.

Mots-clés: Île de Baffin, archéologie, écologie.

Introduction

For more than six decades the excavation of coastal sites occupied during the winter season has been the primary focus of Thule archaeological research. This was the basic format adopted in the first systematic investigation of the Thule culture published in 1927 (Mathiassen 1927) and it has been followed in essentially all studies since then. In more specific terms, this approach involves the partial or complete excavation of semi-subterranean, sod/stone/whalebones houses over other types of sites or site features. These houses constitute the most impressive structural remains of a Thule site and typically yield a broad range of artifactual data. As a result, their analysis has become virtually synonymous with Thule archaeology and continues to form the core of current research.

There is nothing unusual, of course, in archaeologists concentrating their efforts on those cultural phenomena which produce the greatest information yield. However, inherent in the persistence of this approach is the danger of interpreting it as a consensus of opinion that most if not all aspects of Thule prehistory can be resolved using data recovered from coastal winter sites. Among its other drawbacks, such an interpretation discourages analysis of other dimensions of Thule culture which require greater attention. The organization of the summer and fall components of the Thule settlement and subsistence cycle, for example, is a research area of increasing importance to reconstructions of Thule socio-economic organization (e.g., McGhee 1984) but one in which few studies have been initiated.

The most persuasive argument for the persistence of the coastal/winter approach, but one that is largely untested in my view, is that the summer and/or terrestrial facet of the annual socio-economic cycle is data poor (e.g., McGhee 1984:84). That is, summer and fall sites are widely scattered over the landscape making them difficult to locate, and more importantly, they contain insufficient samples of diagnostic artifacts required for traditional comparative purposes. This argument is not without merit, however, it is apparent from discussions with colleagues and from reviewing Thule site reports that analysis of feature types other than sod houses has rarely been a primary research objective, resulting in little time and effort being devoted to their study. There seems to have developed from this a form of popular wisdom which states that the disappointing results of sporadic testing of tent rings and related features (often closely affiliated to winter sites) is sufficient proof that they are of low potential and thus too difficult to systematically examine.

A contributing factor is the belief that available historical sources provide an adequate model of prehistoric summer and fall socio-economics. With linguistic and archaeological evidence demonstrating the emergence of the historic Inuit from a Thule culture base, abstracting elements of Thule adaptive strategies from ethnohistoric and ethnographic sources (e.g., Boas 1888; Jenness 1928; Damas 1969; Balikci 1970) is an accepted procedure. However, while considerable attention has been devoted to the evolution of Thule adaptive processes integral to the winter subsystem, behavioural inferences generated for the summer and fall component are of a much more generalized nature and there have been few attempts to verify them through observation or experiment. In addition, most models dealing with the transformation of winter adaptive strategies from the occupation of sedentary coastal base camps to mobile snow house communities built on the sea ice emphasize the effects on the maritime component (e.g., the influence of changing local or hemispheric climatic patterns on resource abundance and distribution) (see Vibe 1967; McGhee 1969/70; Schledermann 1976; McCartney 1977; Jacobs and Sabo 1978). Whatever constellation of factors was responsible for the changes in the winter facet of the cycle, it is inconceivable that the summer subsystem remained unaffected, particularly since the summer/fall period was one of critical importance to winter survival. Although it is widely recognized that both Thule and historic Inuit were forced into a dual marine/terrestrial economy by the need for winter clothing of caribou skin, there is little accumulated information about the terrestrial component beyond faunal studies demonstrating the importance of caribou hunting and ethnohistorical accounts related to hunting techniques.

Southern Baffin Island

Given that the rationale offered for not examining summer and/or fall sites has some legitimacy, any archaeological investigation of them must begin with the isolation of a region where activities were concentrated enough to leave sufficient information, and southern Baffin Island is an ideal location. In the course of investigating Thule winter sites in Frobisher Bay (Stenton 1983) I discovered a number of references attesting to the former economic importance of the area surrounding Nettilling and Amadjuak Lakes to groups residing in the Cape Dorset, Lake Harbour, Frobisher Bay and Cumberland Sound districts. The well-vegetated lowlands surrounding these lakes attract the largest resident caribou

herd on Baffin Island, and serve as the nesting grounds for a variety of waterfowl. Both lakes support populations of arctic char (*Salvelinus alpinus*), and Nettilling also contains a small population of ringed seal (*Phoca hispide soperii*).

In terms of matters directly related to subsistence economy then, the inland area seemed to have good potential, but in addition, seasonal travel to the interior of Baffin Island by three otherwise geographically distinct groups would provide increased opportunities for social contact. Among other things this would widen the total information pool, the marriage universe, and extend the kin and non-kin network.

An investigation of the Nettilling Lake region began in 1984 utilizing three primary sources of information: ethnographic and historic documentation, oral history and field archaeology. The oldest relevant ethnographic and historic documentation generally dates from the mid 19th century, and ranges in quality from somewhat fictionalized accounts to the classic study conducted by Boas in Cumberland Sound (Boas 1888). Included are the experiences of scientists and explorers (e.g.,Hantzsch 1909; Soper 1925), whalers (Noble 1902) and R.C.M.P. constables from the Pangnirtung and Lake Harbour detachments who travelled via the lakes during their winter patrols (e.g., R.C.M.P. Annual Report 1925). Unfortunately, there are relatively few Inuit authored sources, although Peter Pitseolak's "people from our side" (1974) is an important exception. Though invariably brief, these accounts are all consistent in their assessment of the former importance of the Nettilling Lake for summer travel and hunting. They also contain useful information on travel routes to the interior, settlement location, size and the duration of inland residence.

One of the most important sources of information is the testimony of Inuit informants who have personal knowledge of the study area. Discussions held with twenty informants residing in Cape Dorset, Frobisher Bay and Pangnirtung have considerably expanded upon the written records by providing detailed information on mobility and scheduling patterns during the historic era, as well as on prehistoric site locations.

Three seasons of archaeological investigation along the west shore of Nettilling Lake between Mirage Bay and Burwash Bay have confirmed the apparent substantial utilization of the area by revealing 65 sites which I believe represent only a fraction of the total record. These assume a variety of forms ranging from the single Inukshuk, to multi-dimensional camps comprised of tent rings, semi-subterranean houses, caches, hearths, stone fox traps, burials and shooting blinds. Each of the major cultural groups are represented in the sample (Pre-Dorset, Dorset, Thule and Historic Inuit), providing further evidence of the importance of the interior terrestrial environment.

Patterns of Land Use

Although the basic data from all sources is still under analysis I believe there is compelling evidence that summer/fall land use was more organized than is generally assumed and that at least some of the behaviour has left recognizable patterns. Based on the available information, two general patterns of terrestrial land use emerge for the south Baffin region.

The first involves the establishment of family camps at the heads of local fjords or inlets from which groups of hunters move out for trips of varying duration to hunt caribou. Individuals remaining at the base camp (i.e., old men, women and children) harvest local resources including fish, waterfowl, berries, etc. This pattern would usually entail a shorter move away from the coast and was operative during the historic period by residents of the north and southeast side of Cumberland Sound, the north shore of Frobisher Bay and the south shore of the Meta Incognita Peninsula who relied on small local caribou herds (e.g., Boas 1888; Maxwell 1985: pers. comm.; Stenton n.d.).

Ethnographic sources indicate that land use related to the alternative strategy, in which one or both of the large interior lakes was the preferred destination, differed from the above in assuming one of four forms: 1) groups of hunters travelling to either lake for periods of up to three months, ii) the same trip but involving complete families, iii) two or three extended families spending a winter inland and returning to the coast in the spring, and iv) two or three extended families residing for up to three years on the lakes before returning to the coast. According to Boas (1888:15) men and women (with children and elderly) in both Cumberland Sound and Frobisher Bay travelled separately and along different routes when making these journeys. Although the reasons for this are not fully explained, it was presumably to allow men to devote more time to hunting along the way, and to travel faster and thus monitor game conditions over a greater and different area than that observed by other members of the group. Because of the distances involved and changing overland travel conditions, scheduling a move to take advantage of resource distribution or specific procurement techniques was also an important consideration. Some groups, especially those travelling to Nettilling, apparently preferred to leave the coast in the spring while there was still enough snow cover to make the journey by sledge, while others, after reaching the point of departure (e.g., the head of an inlet) would make the complete journey on foot (e.g. A. Qaqjurajuk 1984: pers. comm.; S. Alainga 1986: pers. comm.). The former arrangement, however, influenced the length of time spent in a specific location by forcing some groups to wait for snow cover before they could make the return journey to the coast by sledge (see Stenton 1986), and those travelling by boat to return prior to freeze-up (Q. Eevik 1986: pers. comm.).

Discussion

The historic data suggest that the most important mechanism underlying the variable forms of land use was changing levels of terrestrial productivity, which was presumably triggered by episodes of deteriorating hemispheric climate (Bryson and Wendland 1967; McGhee 1969/70; McCartney 1977). Many informants have stated that for years it was necessary to travel to the interior to get caribou simply because none could be found anywhere near the coast. There is ample documentation supporting these claims, and when asked to speculate as to the reasons for the reduced abundance of animals, the response invariably centred on "bad weather" (e.g., mild and wet winters). It is also evident, however, that social factors noted earlier helped determine the organization of terrestrial behaviour. Related families from the Markham Bay and Frobisher Bay districts, for example, met every two

to three years at a predetermined location on southeastern Amadjuak Lake, yet it was common for each to hunt in other areas during the interim period. (S. Alainga 1986: pers. comm.). Contact with European whalers, intensified through the establishment of winter ship and shore stations, must also be recognized for its pronounced effects on the traditional seasonal rounds of many Baffin Inuit. Because the whaling season overlapped with the period during which Inuit groups traditionally moved onto the land, this aspect of the seasonal round was often spatially circumscribed if not completely abandoned (see Ross 1979).

What was the nature of the relationship between environmental and social factors during the prehistoric era? To aid in the reconstruction of the influence of the environment on the distribution and behaviour of critical resources we have generated local modern and paleoecological data in the form of moss and lichen pollsters, soil and lake sediment cores (see Fitzhugh and Lamb 1985). Meterological data collected in our own studies and by earlier investigators (e.g., Soper 1925) are also being utilized. Using the ethnographic evidence for the existence of different social groupings related to terrestrial land use as a base, a provisional settlement typology emphasizing site size, location, feature type and artifact/faunal record has been developed to provide insight regarding prehistoric subsistence behaviour.

As noted earlier, much of the data collected for this study is presently under analysis, however, some of the preliminary results are at variance with certain perceptions of summer and fall activities. High residential mobility, for example, is considered by most researchers to be one of the most characteristic elements of the summer and fall adaptation, but in both Mirage Bay and Burwash Bay on Nettilling Lake we have found archaeological evidence of seasonally permanent camps. We have also isolated differences between the archaeological and ethnographic records in relation to site selection and group movements once the interior region was reached, which point to the dangers of the wholesale borrowing of historic Inuit behavioural models. All of the informants who had travelled to the interior under traditional conditions (i.e., prior to motorized transport), for example, stated that the prominent glacial landforms south and west of Nettilling Lake were not primary residential targets or access routes. Yet the archaeological evidence is clearly at odds with this information, with the overwhelming majority of sites located on the crests of eskers and moraines. Change in land use over time is currently most visible in the historic context. The oldest informants, born in the late nineteenth and early twentieth centuries, recall that travel to the interior of the island was an annual summer event and the most important activity was the acquisition of caribou skins for winter clothing. Some meat was dried and packed out for later consumption, however, stockpiling resources for the winter period was not a usual practice. Most younger informants did not travel every year to the interior but often stayed for longer periods of time (e.g., one year or more). Their behaviour was influenced more by subsistence (i.e., food) than the need for clothing since they usually had access to other clothing materials at trading posts. Long-term residence is also suggested in the archaeological record with most sites containing several storage caches, and in one case more than fifty.

Conclusion

One of the original goals of the investigation in central Baffin Island was to demonstrate that the archaeological record produced by summer and fall activities is amenable to study and has the potential to inform us about the organization of past subsistence behaviour. The results to date are very encouraging, and although the inland dimension of summer and fall adaptations has been stressed here, the summer coastal dimension will also require detailed analysis before the necessary integration with the coastal record can begin. It is hoped that the results of the present study will lead to a better understanding of both prehistoric and historic subsistence cycles and promote additional research of the terrestrial environment.

Acknowledgments

The author is grateful for financial and logistical support provided by the Boreal Institute for Northern Studies (University of Alberta) and the Department of Indian Affairs and Northern Development in Frobisher Bay. Completion of the field research could not have been accomplished without the generous assistance of the many Inuit informants on Baffin Island, and Dr. J.D. Jacobs of the University of Windsor.

References

Alainga, S. 1986. Personal communication, Frobisher Bay, N.W.T.

Balikci, A. 1970. The Netsilik Eskimo. University of Toronto Press, Toronto.

Boas, F. 1888. The Central Eskimo. Smithsonian Institution. Sixth Annual Report of the Bureau of Ethnology, Washington.

Bryson, R. and Wendland W. 1967. Tentative climatic patterns for some Late Glacial and Post-Glacial episodes in Central North America. In: Meyer-Oakes, J., ed. Life, Land and Water. University of Manitoba Press, Winnipeg.

Damas, D. 1969. The diversity of Eskimo societies. In: Lee, R. and Devore, I. eds. Man the Hunter. Aldine Publishing Company, Chicago.

Eevik, Q. 1986. Personal Communication, Pangnirtung, N.W.T.

Fitzhugh, W. and Lamb, H.F. 1985. Vegetation history and culture change in Labrador prehistory. Arctic and Alpine Research 17(4):357–370.

Jacobs, J. and Sabo, G. 1978. Environments and adaptations of the Thule Culture on the Davis Strait Coast of Baffin Island. Arctic and Alpine Research 10(3):595–613.

Jenness, D. 1928. People of The Twilight. The Macmillan Company, New York.

Mathiassen, T. 1927. Archaeology of the Central Eskimos. Report of the Fifth Thule Expedition, 1921–24, Vol. 4. Copenhagen.

Maxwell, M. 1985. Personal Communication.

McCartney, A. 1977. Thule Eskimo Prehistory along Northwest Hudson Bay. Archaeological Survey of Canada, Mercury Series Paper No. 70. Ottawa.

McGhee, R. 1969/70. Speculations on climatic change and Thule Culture development. Folk (11/12):173–184. Copenhagen.

_____. 1984. The Thule Village at Brooman Point, High Arctic Canada. Archaeological Survey of Canada, Mercury Series Paper No. 125. Ottawa.

Noble, C. Jr. 1902. Account of travels. In: Millward, A., ed. Southern Baffin Island: An Account of Exploration, Investigation and Settlement During the Past Fifty Years. Department of Interior, Ottawa.

Pitseolak, P. 1974. People From Our Side. Hurtig Publishers, Edmonton.

Qaqjurajuk, A. 1984. Personal Communication, Cape Dorset, N.W.T.

R.C.M.P. 1925. Annual Report of the Royal Canadian Mounted Police, Ottawa.

Ross, W. 1979. Commercial whaling and Eskimos in the Eastern Canadian Arctic 1819–1920. In: McCartney, A., ed. Thule Eskimo Culture: An Anthropological Retrospective. Archaeological Survey of Canada, Mercury Series Paper No. 88. Ottawa.

Schledermann, P. 1976. The effect of climatic/ecological changes on the style of Thule Culture winter dwellings. Arctic and Alpine Research 8(1):37–47.

Soper, D. 1928. A Faunal Investigation of Southern Baffin Island. National Museum of Canada. Bulletin No. 53, Biological Series No. 15. Ottawa.

Stenton, D. 1983. An Analysis of Faunal Remains from The Peale Point Site (KkDo-1), Baffin Island, N.W.T. MA thesis, Trent University, Peterborough.

_____ 1986. A Soper record cairn from Baffin Island, N.W.T. Arctic 39(1):92–94.

_____ n.d. Preliminary Report of 1986 Field Research, Baffin Island, N.W.T.

Vibe, C. 1967. Arctic animals in relation to climatic fluctuations. Meddeleser om Gronland 170(5).

THE IMAGINED REALITY OF THE CANADIAN NORTH

Douglas A. West

Department of Political Science, Carleton University, Ottawa, Ontario, K1S 5B6

Level: Ph.D

Abstract

> "All my life I've been living on the inside of what these other people have been looking at and writing about. And to tell you the truth – which is the whole idea of this book – the outsiders, or what I call outsiders, have written so much baloney that sometimes it's been hard for me to recognize in their books the land and the people that I know so well."
>
> Ernie Lyall, *An Arctic Man*

Ernie Lyall wrote these words with the intention of setting the record straight about what constituted the "real" North in Canada. Having achieved the unique perspective of living "inside" as an "outsider", Lyall took it upon himself to correct the academic and journalistic smugness that usually accompanies reports about the North. His story, while primarily anecdotal, serves as a focus for my own research on the distinction between North and South as conceptual, and therefore political, categories. This conceptual approach allows a greater scope with which to view the North and provides an interdisciplinary perspective that tests the consistency of Northern Studies itself.

At this conference I would like to share my approach to the North with fellow students in order to examine the cogency of my research. My paper will cover the extent of my doctoral research to date and will include a survey of the literature dealing with the cognitive designation of space and place. In addition I will present a speculative outline of the remainder of my proposed project.

Key words: Mental maps, discourse, nordicization.

Résumé

> «Toute ma vie, j'ai vécu au sein de ce que d'autres voyaient de l'extérieur, et décrivaient ensuite. Et, pour dire vrai (ce qui est l'essence de ce livre), ces gens de l'extérieur, ou que je qualifie ainsi, ont écrit tant de fables qu'il m'est bien difficile d'y distinguer le pays et le peuple que je connais si bien».
>
> (extrait de *An Arctic Man*, par Ernie Lyall)

C'est dans l'intention de rétablir les faits réels concernant le Nord canadien qu'Ernie Lyall a écrit ces mots. Étranger vivant au sein de la collectivité nordique, son point de vue interne lui a permis de remédier à la suffisance des universitaires et des journalistes écrivant des articles sur le Nord. Son histoire, largement anecdotique, a permis à l'auteur de mieux circonscrire ses recherches sur les distinctions notionnelles, et donc politiques, entre le Nord et le Sud. Cette approche notionnelle permet d'envisager le Nord d'un point de vue plus ample, fondé sur un effort interdisciplinaire vérifiant la logique des Études nordiques elles-mêmes.

L'auteur désire parler de son approche à d'autres étudiants participant à la Conférence, afin de déterminer le bien-fondé de ses recherches de 3e cycle menées jusqu'à présent, et fait un relevé de la littérature spécialisée traitant de les grandes lignes conjecturales du reste de son projet.

Mots-clés: Représentation mentale, dissertation, nordicisation.

Introduction

The scope of this paper is extremely wide. Therefore, only a glimpse can be provided of the theoretical background which animates my concerns about how the Canadian North has been portrayed by various disciplines. As a student of political theory, I have been exposed to the important work of Michel Foucault whose analyses on the relationship between power and knowledge in the modern age have been received with much controversy. In brief, Foucault argued that power and knowledge, since the beginning of the nineteenth-century (the beginning of social science), have formed an ensemble. Where there is knowledge, or what is considered knowledge, there is power. As a result, power cannot be located in a single source; there are instead various sites of power/knowledge relations. Foucault identified several of these sites in the medical clinic, the mental institution and the prison. Each site had its own specific way of doing things, and consequently its own specific language. Foucault referred to these ensembles of power/knowledge as being mediated by a technical language called a discourse. In short, a discourse surrounds a particular subject, e.g. the criminal, the madman or the sick person, with a set of techniques designed to normalize its activity in relation to standards created by the logic of reason. Moreover, these techniques of normalization, designed in a practical way to ease the individual into society, occur primarily in the West and are a product of the West's concern to improve the condition of Man. Discourses, then, produce that of which they speak; they circumscribe their subject with the rules and procedures.

The other theoretical perspective which animates my concerns about the portrayal of the Canadian North is the apparent arbitrariness of geographical designation. In a very real sense, our sense of direction is arbitrarily defined. We need starting points to determine where it is we are going.

Indeed, geographers have for some time now been concerned with the activity of "mental mapping" yet have, to my knowledge, neglected to notice the political implications of their research. Why do we call the West the West and the East the East? Why does the line of 0° longitude dissect England? The answers to such questions will reveal much about our obsession with measurement and order.

By using Foucault's notion of discourse I have been able to provide an answer to these questions, albeit a very clumsy and unsophisticated one. What needs to be done is a careful analysis of the techniques of normalization which have produced our ideas of space and place. In 1978, Edward Said published a book on *Orientalism*; the first time discourse theory had been applied to the concept of territoriality in an analysis of the production of the Orient. It is in this context that the following sketch of the northern or nordic discourse must be placed. My research is at a beginning, thus, the sketch will appear quite ill-defined. This is work that is very much in progess.

In an interview published in 1972, Michel Foucault was asked if there was any place for Geography in his "archaeology" of knowledge. Foucault's initial response focussed on his use of geographical metaphors to describe the effects of power/knowledge relations in the analysis of discursive practise. The concepts of territory and field were geographical notions which Foucault had appropriated without much thought as to their significance for geographers. Moreover, they helped him to explain the configurations within a discursive practise; a discourse operates within a specific region of activity. When confronted with the fact that Geography "grew up in the shadow of the military", Foucault argued that

> Once knowledge can be analyzed in terms of region, domain, implantation, displacement, transposition, one is able to capture the process by which knowledge functions as a form of power and disseminates the effects of power. There is an administration of knowledge, a politics of knowledge, relations of power which pass via knowledge and which, if one tries to transcribe them, lead one to to consider forms of domination designated by such notions as field, region and territory. And the politico-strategic term is an indication of how the military and the administration actually come to inscribe themselves on both a material soil and within forms of discourse.[1]

Because the individual is a product of a "relation of power exercised over bodies", one could extend the analysis of power/knowledge relations to include the politico-strategic adminstration of new territories. A discourse of America comes to mind as does a discourse of colonialism. Furthermore, according to Foucault, "there is much that could be said as well on the problems of regional identity and its conflicts with national identity." Is it possible that regionalism, or the struggle for regional representation takes place within a dynamic site of power/knowledge relations? Is the region, that vagary of geographical generalization, itself a product of the same sort of discursive practise? The extensive activities of adventurers and explorers in the centuries following the "discovery" of the New World, and the consequent proliferation of administrative, academic and political activity in the collecting, mapping and controlling of new territories suggests that some correlation must be made between power and the creation of knowledge of these areas. It is in the concept of "geopolitics" that the initial departure occurs. As Foucault suggested,

> One theme I would like to explore in the next few years is that of the army as a matrix of organisation and knowledge; one would need to study the history of the fortress, the 'campaign', the 'movement', the colony, the territory. Geography must indeed lie at the heart of my concerns.[2]

Foucault had the remarkable affliction of opening more avenues for research than he had time to pursue. He spent the last years of his life searching for a foundation for ethics in the post-modern age and died before ever entering the mundane world of Geography.

It is to that world that I would like to move in order to evaluate what I will call the discourse of the North. It will be the theme of this paper that the North was created and continues to be created and administered within the context of a discursive practise. I will confine my intensive study to the Canadian North. The essential feature of my research is its inter-disciplinary perspective, following the lead of Edward Said whose work on the concept of "orientalism" represents the first attempt to conceptualize the influence of discourse upon territoriality.

Orientalism defined not only the creation of the Orient as a concept, but also the ongoing description of the oriental way of life, language and meaning. It is primarily a discourse or normalization, a language about a specific geographical area as well as a corporate institution for dealing with the Orient. It is in this context that I would like to place the North.

The relationship between Canada and its northern region is and always will be one of power. In the seventeenth and eighteenth centuries the conquest involved the search for the North-West passage to the East. In the nineteenth and twentieth centuries the focus shifted to the reaping of natural resources. With the discovery of oil at Norman Wells in the 1920's, the viability of Northern settlement by southerners became increasingly topical. Moreover, a new discourse about the North began to develop. No longer a barren, cold wasteland that beckoned only the adventurous, the North had become Canada's destiny. Although the rhetoric took a number of decades to develop into a coherent public policy, the North had become the object of an extended Canadian sovereignty. The voyages of J.E. Bernier were made on behalf of the Canadian government seeking to establish territorial control over all lands between its charted northern border and the North Pole.

The new discourse about the North took the form of a nationalistic myth; the North belonged to Canada because it was a natural extension of its political mandate. The "Nordic" discourse also encouraged the coordination of research about the North by providing a standardized set of definitions that remains to this day a vital component of the academic enterprise called Northern Studies. My contention is that this discourse actually created the North as a kind of willed human work. Moreover, a careful and systematic examination of the North allows us to more easily understand the

South. In short, the North represents the "other" to the southern culture and way of life. Jim Lotz once argued that Canada's North had "suddenly become a mirror to the nation." Because it is a place where national conflicts are fought out, it also helps to define the values of the nation. Environmentalists and exploiters, conservatives and radicals argue over the "right" way to develop the North. This attitude, that somehow the North must be brought into the modern world, has occasioned a dialogue amongst Northern researchers in all areas of activity. We must keep in mind, however, that the debate about the North usually takes place in the South and most often amongst southerners. Only recently have Native Northerners begun to enter the dialogue and then it has been qualified by southern rules of conduct. The North will always remain the "other" to the South until the fast-approaching day when it ceases to exist as a separate entity and is smothered by the language of rights and self-government.

Edward Said, in his extremely valuable analysis of the study of the Orient, argued that imaginative geographical speculation led to the creation of an Orientalist discourse that, over time, became increasingly complex and sophisticated. This discourse developed ostensibly as an academic exercise in the definition of the "otherness" of the Orient. In this context he wrote,

> ...this universal practise of designating in one's mind, a familiar space which is 'ours' and an unfamiliar place beyond 'ours' which is 'theirs', is a way of making geographical distinctions that can be entirely arbitrary.[3]

Orientalism, then, is a discipline, a language about a specific geographical area as well as a corporate institution for dealing with the Orient. The production of the Orient provides a valuable source of information for government policy-making. In fact, Said argued that the greatest thrust of the Orientalizing spirit came during the post-Enlightenment period in Europe, also characterized by its nationalistic zeal.

In the same way the North was and is a product of a European consciousness, a North American consciousness, and most recently a Canadian consciousness. In each case the Northern or Nordic discourse was formulated around a number of geographical, ideological and philosophical precepts. Furthermore, in each case reports about the North allowed the North to speak in the language of the South. Knowledge of the North, then, makes it more manageable. Language, as the vehicle for power and management, is created and constantly modified until it no longer simply helps us to understand, it designates the parameters of our understanding. The successive waves of interest in the North are variations on a theme of creation and control, each having its own presuppositions about the North as a geographical topos that requires cataloguing, classification and clarification. For convenience, one can divide the analysis of the study of the North into two periods. Pre-1940, we detect the development of a web of administration involving the geographical classification of the North both physically and socially. Engaged in this enterprise were the original European explorers, surveyors and missionaries as well as the Hudson's Bay Company and the R.C.M.P. (N.W.). Post World War II reveals an intensified interest in the North as a strategic military possession and as a source of mineral wealth. This period is also characterized by the sophistication of the Nordic discourse, with the consequent development of Northern Studies programmes. The intensification of Northern research tightened the hold on the North while making it more manageable at the same time.

In order to understand the significance of "creative geography" we must briefly examine the proliferation of Northern myths that have allowed successive generations to lay claim to its management. J. Wreford Watson, a noted British geographer, corroborated Said's conception of the "geography of the mind" when he wrote that,

> The geography of any place results from how we see it as much as from what may be seen there. Not all geography derives from the earth itself, some of it springs from the 'idea' of the earth.[4]

Men adjust to this creative geography more easily than to the real thing. In other words, the idea that someone has about a certain region or area will influence his desired use of that area. The voyage to Canada was originally interpreted as a way to the East. However, as mental perceptions changed, so did the geography. For example, the barrenness of the Canadian prairie as a dull, non-prolific, infertile wasteland was characterized as such due to the absence of trees. As the prairies were settled, this absence became less important than the potential for grain-growing. Watson suggested that the North had gone through a number of similar geographical and mental transformations.

> Thus, the 'North' has been different things to different ages as various mental pictures about it have been built up, discarded, reviewed or modified with changing perceptions. To speak about 'the' geography of the North is nonsense; there have been as many geographies as there have been illusions.[5]

The early Norse travellers characterized the Canadian North as "Helluland" or the Great Waste. Cartier labelled it the "land God gave Cain". By the time the North had entered the Canadian consciousness it had become a land of opportunity. Enthusiasm spread and what is now known as the "geography of double illusion" occurred as both perceptions persisted well into the twentieth-century. In Canadian mythology, then, the North has always been an ambiguous term. At once it is a colony and a homeland, a money-making prospect and a bad risk, a unique political environment and a variation of Democracy. In short, the perception of place is determined by the place of perception. This preoccupation with definition frames the parameters of the Nordic discourse; it is an object that requires the circumscription of knowledge. The North is that which is produced by this circumscription.

In a general sense, Canada has always been portrayed as a northern country. According to Carl Berger, northern images "denote not merely geographical location or climatic condition but the combination of both, moulding racial character." [6] The term northern, from this perspective, is synonymous with strength and self-reliance. Moreover, the rhetoric of the turn of the century Canada First Movement

"turned the Canadian climate into a dynamic element of national greatness." [7] The Norman blood that ran in the veins of both French and English Canadians guaranteed a stable political society.

The development of the North became an imperative given its natural resources and its strategic importance. However, after the second world war, development became a double edged question. The influence of the American government jeopardized the sovereignty of the Canadian people. The policy of laissez-faire was increasingly criticized. The consequence of this criticism has been an opening of the northern field. The North has become a training ground for everything from sociology to watershed ecosystem analysis. Although the terminology has changed, the subject remains the same. In other words, the myth of the North is alive and well, and in many ways is analogous to Said's depiction of the myth of the Orient. Both attempt to generally define a geographical area. Both have evolved in response to the changing perceptions about their viability as areas of concern for academics and governments. As the Orient was Orientalized, so too has the North been Nordicized. From this general discussion we can conclude that the North is not a stable object, it moves with the prevailing "creative" wind. What is left for discussion are the mechanisms with which the object is made to move in a practical sense. For, what lies at the heart of discursive formation is not an idea after all, rather it is the practise out of which the discourse is produced.

Nordicizing the North

In 1978, Louis-Edmond Hamelin attempted a survey of all the terms usually associated with the definition of the North in Canada. The word 'polar' was adopted by the Scott Polar Institute and the American Geographical Society. It was used to describe glaciated areas and the territory inside of the Arctic and Antarctic circles. The word 'arctic' had a long history of usage and was used along with other terms such as inner, outer, low, middle and high to delineate specific regions within the North itself. The term 'boreal' was used by botanists and geographers to denote a cold climate. The term 'North' was "originally used to express an idea of relative place", but now referred to the whole region. In this context Hamelin argued that,

> It (North) signified something far off – something vast, hostile, dangerous, unknown, almost unimaginable. Gradually, some of the mysteries of the Far North were replaced by more objective data.[8]

In short, 'North' has become the dominant term used by researchers in all fields. Around it, says Hamelin, "is developing a new technical vocabulary." Most accept the North as that area beyond sixty degrees latitude. Hamelin also noted the use of the words 'nordic', 'nordicity' and 'nordist' as defining culture and those who study it. The creation of a standardized language signifies the end of an important phase of scholarship about the North, the phase that nordicized the North as the Orient was orientialized.

This process of nordicization began with the explorers and ended with the proliferation of projects in the North aimed at creating a more efficient administration of the region and its inhabitants. The following will be a brief survey of this activity.

According to R.A.J. Phillips "the North was long a symbolic goal for man voyaging to discover the most distant parts of his earth."[9] He corroborated Hamelin's denotation of the North as that area beyond sixty degrees latitude while attempting a survey of the traditional thought about Eskimo culture. Captain George Francis Lyon, who ventured into Hudson Bay between 1821 and 1824, recorded the Eskimo way of life. Lyon's detailed summary "more than any other source ... formed the basis of popular writing about the Eskimo."[10] Lyon characterized them as a peaceful people who were constantly defending themselves against attacks from the more bellicose Indian tribes to the South. More importantly, Lyon noted that they had no written language and a very strong oral tradition.

Earlier, Martin Frobisher had described the Eskimo as strange and beastly. In fact, Frobisher's curiosity led him to take back an Eskimo to England for further study. Other explorers in the North began to make detailed maps and developed a literature on how to "do" the North. Eventually, the fur trade became the impetus for further exploration of the region as markets were found in Europe. In short, the North became an adventurers' and entrepreneurs' paradise. Most important, however, were the depictions of the climate and the native inhabitants which fed curiosity while initiating scholarly investigation. The constellation of reports, private journals, geographical surveys and studies of the Eskimo way of life, gave the North a more specific mental location. Moreover, the Northern mythology was fuelled by the tragic voyage of Sir John Franklin, who in 1845 left England in a ship reinforced with steel to protect it from the ice and complete with all the fineries of English life to protect it from the savagery of life in the North. In short order it disappeared and a mythology has grown up around it. Others attempted to live with the Eskimos but more often it worked the other way. According to Phillips, "the dependence of native peoples on the newcomers became so fixed and complete that ways of life had to be changed to fit the European's whims and his economy."[11] In 1670, The Hudson's Bay Company was given Rupert's Land as its empire. The North became a business. It was mapped and charted extensively and Natives began to work for rival European companies. Each camp of traders had a Native contingent and the white man's rules stipulated that only one Native would represent the group in the discussion of camp policy.

The second wave of civilization came to the North with Missionaries. As late as 1948, the religious mission in the North could still be described in the same way that it was carried out in the nineteenth-century. In *Canada Moves North*, Richard Finnie argued that,

> Missionaries in general take it as axiomatic that all natives who are pagans, that is non-Christians, should be converted, and that they are not accustomed to admitting the validity of aboriginal religions.[12]

Most importantly, missionaries established a vital link between government administration and the Native population and white settlers. The "peaceful conquest" of the region as a "natural duty for Canada" occasioned significant social and cultural adjustments. By the 1880's, the missions had developed a policy of bringing Native children to stay at government funded boarding schools, a practise which today is still widespread in the North. While missionaries participated in the enculturation of the Natives, they also assisted white settlers to further explore the region by smoothing their entry into Native controlled lands. Consequently, the officers of the H.B.C. became "virtually un-crowned monarchs" in the North.[13]

Missionaries and traders also acted as intermediaries between the North and scientific organizations like the Smithsonian Institute in Washington. Many museums and libraries requested artifacts for their collections, thus allowing scholars to more easily understand and classify the North without having to go there. This phenomenon is analogous to the "collection" of the Orient as it was described by Said. The post-Enlightenment period in Europe was replete with evidence of a zealous desire to collect everything that was not European. In the same way, the North was assembled, collated and bound into encyclopaedia.[14] Because popular accounts of Eskimo life came from the impressions of travellers in the North, most presented them in a favorable light. For example, in *Arctic Patrols*, a book of tales about the adventures of a member of the R.C.M.P., the author romanticizes life in the North and portrays the Eskimo as a noble savage. In another work, entitled *Thawing out the Eskimo*, a French Jesuit missionary refers to the Eskimo tradition as "meagre and vague". He advises people from the south not to be worried about the swarthy appearance of the average Eskimo.

> Besides his ingenuity, the Eskimo is gifted with a positive love of work. He enjoys, to be sure, his moments of relaxation, but idleness for its own sake he never seeks, much less does he cultivate it. He can be trusted to work steadily and methodically, without being watched.[15]

In a general sense, the popular literature about the North ranged from swashbuckling adventure to tales of the Mounties bringing civility to the North. Popular literature, then, was as much a factor in the determination of the Northern discourse as were academic studies. However, it was only when the government of Canada became involved with the North in a formalized manner, that the agency for the centralization of 'nordicity' emerged.

The Canadian government's formal involvement in the North began in 1870 when sovereignty over the territory of Rupert's Land was ceded to the federal government from Britain. This began what Morris Zaslow referred to as "the quiet Canadian way to build empires; first you create an official and then designate him an area of surveillance."[16] In 1873, the North-West Mounted Police force was created to maintain law and order in Canada's newly acquired territory. The main purpose, however, lay with the question of sovereignty.

> Most of the Canadian government's sporadic forays into the North from 1880 onwards were motivated by the reaction of politicians and officers to aliens in the Arctic. There was nothing else in the North for the government to be concerned about.[17]

The Canadian government displayed a degree of reluctance in accepting its mandate in the North, at first, but after the Klondike Gold rush it was decided to enhance the powers of the territorial administrations in Yukon and in the Northwest Territories. Moreover, the Royal Canadian Signal Corps set up a communications network between the Mackenzie Valley and Yukon. The federal government sponsored the voyages of J.E. Bernier to help establish the Canadian claim to sovereignty and the discovery of oil at Norman Wells suggested the large-scale economic potential of northern natural resources.

However, it was during World War II that the federal government's involvement in the North was greatly expanded. The North had become extremely important for the Allied defence of North America, and as a location for staging bases for military operations in Europe and the Pacific theatre. During the war, airfields, the Alaska highway, radio and weather posts and pipelines were constructed largely with American funding. In fact, at the height of the war, American residency in the North outnumbered Canadian three to one. The question of Canadian sovereignty became more acute. For this reason, in 1946, the R.C.M.P. expanded its northern division and the Canadian army took over the operation of the Alaska highway. In 1947, "... an advisory committee on Northern Development was established in Ottawa to be a clearing house for all new and renewed Dominion government projects in Northern Canada."[18]

The post-war period was characterized by the increasing number of government projects in the North. Morris Zaslow reminds us that the Department of Mines and Technical Surveys was instructed to "fill in the white spaces on the map" so as to complete the geographical circumscription of the region. The North was now contained in the completed surveys and could be investigated with regard to other important criteria or northerness.

It was in the area of public health that the federal government first ventured in the name of creating an effective social policy for the North. According to David Judd, "disease in the North became a kind of national obscenity, not only a threat which might contaminate the south, but an insult as well".[19] By 1956, one-sixth of all Eskimos were being treated for tuberculosis. The issue of sovereignty was overshadowed by the need to deliver effective social programmes to Canada's "forgotten" Natives in the North. In this context, we can argue that the North began to lose the status of the "other" to the south. Slowly it was drawn into the welfare net that was spreading across the country. Authorities in Ottawa, working closely with Health officials sought ways to modify the lifestyles of Natives so they would remain closer to medical facilities. Under the name of prevention, Natives suspected of suffering from T.B. were hospitalized. While this action succeeded in lowering the death rate amongst the Native population, it also necessitated the creation of a file on each Native allowing the government the opportunity to keep track of the population.

> The North quickly moved from being neglected to becoming one of the most efficiently surveyed regions of Canada with annual X-rays of as much as eighty per-cent of the scattered population.[20]

Moreover, welfare programmes and rehabilitation centres were established to smooth the Natives' transition to the white way of life. Education became "the most staggering social task"[21] and the main concern was "to add new intellectual depth without unduly disturbing the social fabric."[22] It is an understatement to argue that by this point the social fabric had already been unduly disturbed. Pursuant to this argument, Hugh Brody noted that southern whites had created "little Canadas" in the North and that "the North was intended to become more like the South."[23] This event was encouraged by the "saving" function of religion, the "helping" function of the administrator and by the "civilizing" function of education. However, even though it was intended that the North become more like the South, the result has been the opposite. Northern qualities have become more specific. There is a specific northern climate, a specific northern style of education, a specific structure of northern religious practise, a specific structure of northern languages and most recently, specific types of northern political and social community. All specificities, however, are measured against those of the South. Development of the North, then, seems to be a cultural expression of the South. The "otherness" of the North is preserved in textbooks and learned journals that take the North as the object of their inquiry. The North was to become a part of a greater Canadian nation. The simplicity of this motivation is usually attacked from the perspective of the precarious existence of northern culture. The development of the North was not motivated by the wish to eradicate the mysterious "other". Rather, it followed logically from the requirements of discourse. In order to survive, a discourse requires ever-changing perspectives for application. It requires more things to normalize. Consequently, a proliferation of Northern Studies Programmes and a general widespread interest in the future of "northern alternatives" have occurred.

In 1972, DIAND released a policy statement that would encourage Native northerners to adapt to their changing environment.

> The real need is to concentrate on the means of enhancing the Eskimo's self-respect and livelihood especially through diversified education and vocational training and fundamentally to give them mobility and freedom of choice.[24]

The Native northerner seeks to become the government representative of his own cultural protection. In addition, he has become a businessman who is learning how to barter more effectively with his cultural heritage. What is important to note here is that the Northern culture was never self-expressed in any way different from how culture is self-expressed in the South. It is expressed with terms like "rights" and "freedom" and "land claims", all of which are products of the South. Thus, the latest perspective on the North is no less part of the normalization or the "nordicization" process than was any which preceded it. Indeed, in order to initiate cultural and political awareness of northern peoples, they first must be taught what is meant by culture and what kinds of political institutions are at their disposal. In the end, the North is administered by itself, thus closing the discursive circle.

Said's depiction of the Orient concluded with the observation that the dynamism of the region was dependent upon the dynamism of the discourse. Similarly, the dynamism of the North is kept alive by the academic and administrative community. In short, the North remains forever a land of discovery. The Northern Research and Coordination Centre of DIAND was originally mandated to coordinate all research regardless of the perspective from which it was to be pursued. Northern research "involves the mapping of the land, and the bottom of the ocean, the collecting of insects, the analysis of glaciers, pure physics, the design of underwear, town planning and linguistics."[25] What was begun by the collection of "objective" data about the North has become a business. It also became an academic exercise that saw indigenous languages moulded and shaped to fit into a standardized form that is more easily communicable. The same thing happened in the philological laboratories of Europe. While European philologists experimented with the Oriental languages, two missionaries, Rev. James Evans and Rev. E.J. Peck, created syllabic writing for the Cree Indians and the Eskimos respectively.[26] Moreover, not long after the creation of the Department of Northern Affairs in 1953, a programme was begun to create a standardized form of the Eskimo language that could be understood by all northern Natives. To this end they began publishing *INUKTITUT*, a periodical written by Eskimos, for Eskimos, in 1959.

Today, a myriad of projects from ethnological reviews of culture to housing developments exist within the various departments of the federal and provincial governments, and are supported by the academic institutions of the country. Moreover, not only is there coordination of research projects, there are those who teach Native Studies to Natives and non-Natives alike. The North is studied historically, legally, geographically, culturally and politically.

Just as the Orient belongs to Orientalism, so now the North belongs to Northern Studies. In fact, the centre of the Nordic or northern discourse lies in the university. Benjamin Disraeli once said that the East was a career. The North is a career but it is also a business.

Conclusion

The foregoing analysis of the literature and history of the Canadian North is obviously incomplete. My intention was to provide a glimpse at a new, general theoretical perspective on the "Northern problem". This rude sketch is a blueprint for further research into ways in which the Canadian North has been produced for mass consumption. The activities of academics and administrators have produced specific ways of speaking about the North. Moreover, my intention was not to admonish these activities but to point out what we are doing there. Too often the North is simply taken for granted, thus before we can really discuss what alternatives are open for Northern development we must ask ourselves how this object that requires development came into being and how it has been produced over time.

References

1. Michel Foucault. Power/Knowledge, N.Y:Panther, 1972, p. 69.
2. Ibid., p. 72.
3. Edward Said. Orientalism, New York:Vintage Books, 1978, p. 43.
4. J.W. Watson. "The role of illusion in North American geography:A note on the geography of North American settlements". Canadian Geographer Vol. 13, 1969.
5. Ibid., p. 26.
6. Carl Berger. "The true North strong and free" in Nationalism in Canada ed. Peter Russell, Toronto:McGraw-Hill, 1966, p. 5.
7. Ibid., p. 7.
8. Louis-Edmond Hamelin. "A circumpolar index" in Canada's Changing North ed. William C. Wonders, Toronto:Maclelland & Stewart, 1971. pp. 7-9.
9. R.A.J. Phillips. Canada's North, Toronto:Macmillan, 1967, p. 31.
10. Ibid., p. 45.
11. Ibid., p. 72.
12. Richard Finnie. Canada Moves North, Toronto:Macmillan, 1948. p. 38.
13. Morris Zaslow. The Opening of the Canadian North, Toronto:Maclelland & Stewart, 1971. p. 20.
14. Said op.cit. pp. 73-92.
15. Rev. A.G. Morice. Thawing Out The Eskimo, trans. Mary T. Laughlin, Boston:Society for the Propagation of the Faith, 1943. p. 76.
16. Zaslow op.cit. p. 96.
17. David Judd. "Canada's northern policy:retrospect and prospect" in Canada's Changing North ed. William C. Wonders op.cit. p. 338.
18. Ibid., p. 343.
19. Ibid., Chapter on Public Health in the North.
20. Ibid., p. 344.
21. Phillips op.cit. pp. 219-225.
22. Ibid., p. 22.
23. Hugh Brody. The People's Land, Toronto: Penguin Books, 1975. p. 35.
24. Canada's North 1970 - 1980. Ottawa:DIAND, 1972. p. 24.
25. Phillips op.cit. p. 273.
26. Ibid., p. 273.

Bibliography

Berger, Carl. "The true North strong and free" Nationalism in Canada ed. Peter Russell. Toronto: McGraw-Hill, 1966.

Brody, Hugh. The People's Land Toronto:Penguin Books, 1975

Campbell, Captain William. Arctic Patrols:Stories of the Canadian Mounted Police Milwaukee: The Bruce Publishing Company, 1936.

Cruikshank, Julie. "Myths and Futures in the Yukon Territory:The Inquiry as a Social Dragnet" 1978 MS.

Dacks, Gurston. A Choice of Futures Toronto: Methuen, 1981.

Dosman, E.J. The National Interest:The Politics of Northern Development 1968-1975 Toronto:Maclelland and Stewart, 1975.

Dosman, E.J. and Frances Abele "Interdepartmental co-ordination and northern development" Canadian Public Administration Vol. 24, No. 3, 1981. pp. 428-445.

Dreyfus, Hubert and Paul Rabinow. Michel Foucault: Beyond Structuralism and Hermeneutics Chicago: University of Chicago, 1982.

Finnie, Richard. Canada Moves North Toronto: MacMillan, 1948.

Foucault, Michel. Power/Knowledge New York: Pantheon, 1972.

Hamelin, L.-E. "A circumpolar index" Canada's Changing North ed. William C. Wonders Toronto: Maclelland and Stewart, 1971.

_____ , Canadian Nordicity: It's Your North Too trans. William Barr Montreal: Harvest House, 1978.

Judd, David. "Canada's northern policy: retrospect and prospect" Canada's Changing North ed. William C. Wonders Toronto: Maclelland and Stewart, 1971.

Kupsch, Walter ed. The University and the Canadian North Ottawa: Government of Canada, 1973.

Lesage, Jean. "Development of the North" (speech) Ottawa: Government of Canada, 1954.

Lotz, Jim. Northern Realities Toronto: New Press, 1970.

_____ . Government Research and Surveys in the Canadian North. Ottawa: Department of Indian Affairs and Northern Development, 1980.

_____ . "Northern alternatives" Arctic Vol. 28, 1975, pp. 3-8.

Morice, Rev. A.G. Thawing Out the Eskimo trans. Mary T. Laughlin Boston: Society for the Propagation of the Faith, 1943.

Mowat, Farley. Canada North Now: The Great Betrayal Toronto: Maclelland and Stewart, 1972.

Phillips, R.A.J. Canada's North Toronto: Macmillan, 1967.

Ross, Colin. Northern Studies Ottawa: Borealis Press, 1975.

Russell, Peter ed. Nationalism in Canada Toronto: McGraw-Hill, 1966.

Said, Edward W. Orientalism New York: Vintage Books, 1978.

Watson, J.W. "The role of illusion in North American geography: A note on the geography of North American settlements" Canadian Geographer Vol. 13, 1969, pp. 10-27.

Wonders, William C. ed. Canada's Changing North Toronto: Maclelland & Stewart, 1971.

Zaslow, Morris. The Opening of the Canadian North Toronto: Maclelland and Stewart, 1971.

Government Documents

Alberta, Northern Alberta Development Council, Goals for Programs, 1979.

Canada, DIAND Native Opportunities: Course and Programme Guide at Canadian Colleges and Universities Ottawa: 1980.

Canada, Information Canada Science and the North Mont-Gabriel, Quebec, 1972.

Canada, Science Council Report #26, Northward Looking: A Strategy and a Science Policy for Northern Development August, 1977.

Canada, Department of Indian and Northern Affairs Canada's North Today Ottawa, 1981.

Canada, Department of Indian and Northern Affairs Canada's North 1970-80 Ottawa, 1972

Other Sources

Card, B.Y. ed. Prospectives on Regions and Regionalism Edmonton: Western Association of Sociology and Anthropology, 1968.

Finnie, Richard. The Lure of the North Philadelphia: D. McKay, 1940.

Hamilton, Alvin. "Resources for tomorrow" (speech) Department of Northern Affairs and Natural Resources Ottawa, 1959.

Jenness, Diamond. Eskimo Administration: II Montreal: Arctic Institute of North America, 1964.

Judd, David. "Seventy-five years of resource administration in Northern Canada" The Polar Record Vol. 14, No. 93, 1969, pp. 791-806.

Morton, W.L. "The North in Canadian history" Canada's Changing North Toronto: Maclelland and Stewart, 1971.

Robertson, R.G. "The future of the North" North, Vol. 8, 1961, pp. 1-13.

Underhill, F. ed. The Canadian Northwest: Its Potentialities Toronto: University of Toronto Press, 1959.

Williamson, R.G. "Regions and identity in the North: some notes" Prospectives on Regions and Regionalism ed. B.Y. Card Edmonton: Western Association of Sociology and Anthropology, 1968.

ASSOCIATION OF CANADIAN UNIVERSITIES FOR NORTHERN STUDIES
ASSOCIATION UNIVERSITAIRE CANADIENNE D'ÉTUDES NORDIQUES

PUBLICATIONS

The Use of Greenlandic and Danish in Greenland Schools, 1980

Some Thoughts on the Current State of Teaching and Research about Northern Canada. T.H.B. Symons, April 1980

Proceedings of the First International Symposium on Renewable Resources and the Economy of the North, M.M.R. Freeman (ed.), 1981.

Ethical Principles for the Conduct of Research in the North/Principes d'éthique pour la conduite de la recherche dans le Nord, 1982 (also available in Inuktitut)

Resources and Dynamics of the Boreal Zone: Proceedings of a Conference held at Thunder Bay, Ontario, August 23-26, 1982, R.W. Wein, R.R. Riewe and I.R. Methven (eds.), 1983.

List of Northern Specialists at Canadian Universities/Liste des spécialistes du Nord dans les universités canadiennes, 1983

Social Science in the North: Communicating Northern Values, 1984.

Federal Government Resources for University Research and Science Training in the North/Ressources du gouvernement fédéral pour la recherche et la formation scientifique dans le Nord, 1984.

Guide to Northern Science Licences and Permits/Recherche Nordique — Répertoire des licences et permis, 1984.

Distance Education in the Canadian North: An Annotated Bibliography, 1984.

Canada's Northern Stations, G.T.J. Campbell and W.P. Adams (eds.), 1986.

Arctic Heritage, Proceedings of a Symposium, J.G. Nelson, Roger Needham and Linda Norton (eds.), 1987.

Education, Research, Information Systems and the North, W.P. Adams (ed.), 1987

Canada's Subarctic Universities/Les universités canadiennes du Moyen-Nord, W.P. Adams and D. Parker (eds.), 1987.

Student Research in Canada's North/Les recherches des étudiants dans le Nord canadien, W. Peter Adams and Peter G. Johnson (eds), 1988

Tenth Anniversary Report of ACUNS/Rapport du dixième anniversaire de l'AUCEN, W. Peter Adams and Frank Duerden (eds), 1988

The ACUNS newsletter *Northline* appears four times a year, and is available free on request./Le bulletin de l'AUCEN *Point Nord* paraît quatre fois au cours de l'année. On peut l'obtenir gratuitement sur demande.

Association of Canadian Universities for Northern Studies
Association universitaire canadienne d'Études nordiques

The Association represents thirty-four Canadian universities active in northern studies, research and training. Founded at Churchill, Manitoba in 1977, it is a federally incorporated charitable organization.

The purpose of the Association is the advancement of northern scholarship through education, professional and scientific training and research.

L'Association représente trente-quatre universités canadiennes actives dans le domaine des études, de la recherche et de la formation sur le Nord. Fondée à Churchill, Manitoba en 1977, c'est une organisation charitable, à but non lucratif et incorporée.

L'objectif de l'Association est l'avancement de l'érudition nordique, grâce à l'éducation, la formation professionnelle et scientifique, et la recherche.

●

BOARD OF DIRECTORS/CONSEIL D'ADMINISTRATION 1987–89

President/Président	Marc-Adélard Tremblay, Université Laval
Vice-President/Vice-Président	John K. Stager, University of British Columbia
Secretary-Treasurer / Secrétaire-trésorier	Frank Duerden, Ryerson Polytechnical Institute
Director/Directeur	James B. Carefoot, University of Regina
Director/Directeur	Hugh M. French, University of Ottawa
Director/Directeur	Marianne Stenbaek, McGill University
Director/Directeur	Geoffrey R. Weller, Lakehead University

●

MEMBERS/MEMBRES

University of Alberta • Brandon University • University of British Columbia • University of Calgary • Carleton University • Concordia University • Dalhousie University • Ecole Polytechnique • University of Guelph • Lakehead University • Laurentian University • Université Laval • University of Manitoba • McGill University • McMaster University • Memorial University • Université de Montréal • University of New Brunswick • University of Ottawa • Université du Québec à Chicoutimi • Université du Québec à Montréal • Université du Québec en Abitibi-Témiscamingue • Queen's University • University of Regina • Ryerson Polytechnical Institute • University of Saskatchewan • Simon Fraser University • University of Toronto • Trent University • University of Victoria • University of Waterloo • University of Western Ontario • University of Windsor • York University